28/3/2017

AL:daerey...

EE 341

Et 342

2015/3/16

A W G — American wight gush

text book

+ power system Analysis

by Had - + saadat

+ stevenson

1: parameters of a head line

2- Line models

- Complex power flow.

3- Line Compensitlow.

4- Cables

CMIL $\frac{1}{1000 \text{ in}}$

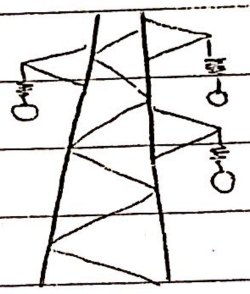
1 inch = 2.54

(R , L , C , G)

* ① Conductance (G) :-

① Leakge Current (power losse)

نضير لما يكون في زوساخ على الحارل



② Corona :- (Losses)

O O bundle نستخدم

$|I|^2 R >>>$ Corona loss + lakeye l

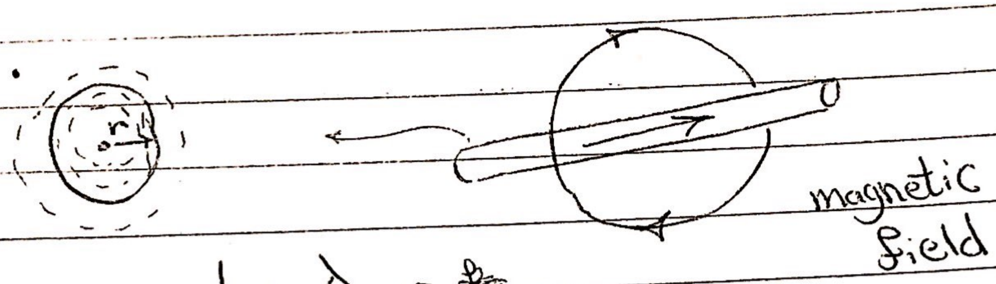
ولهذا نعتبر (G) مهملة لان تأثيرها صغير

...an aluminum stranded conductor (1113000 cmil) has Rdc=0.0155:E-3 omhs/ft at 20 C and Rac, 60-HZ=0.0951 ohms/mile at 50 C. Assuming 1.6% increase due to spiraling. a- Verify Rdc at 20C. b- How much increase in R due to skin effect.

28/3/2017

inductance (L) :-

inductance of a single Conductor

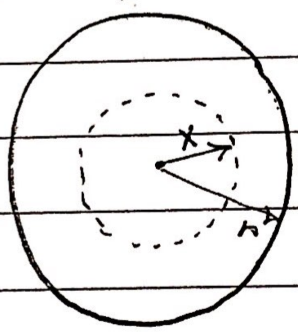


$L = \frac{\lambda}{I}$ →

For non-magnetic material $L = \frac{\lambda}{I}$ H → (1)

i ⊕ induced Voltage

$\lambda \equiv$ total flux Linkages (Web-turn)



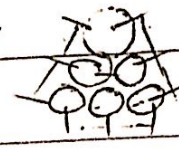
$$\int_0^{2\pi x} H_x \, dl = I \longrightarrow (2)$$

H_x = magnetic field intinsity

شدة المجال المغناطيسي

$H_x = \frac{I_x}{2\pi x} \longrightarrow (3)$

$(d)^{16} (2d)^{6} (k)^{2} ($



I_x = Current enclosed at Radius (x)

internal inductance (L int) :-

For uniform current distribution

$$\frac{I}{\pi r^2} = \frac{I}{\pi x^2} \longrightarrow (4)$$

(4) into (3) for I_x :-

$$H_x = \frac{1}{2\pi x} \cdot \frac{I \cdot \pi x^2}{\pi r^2} = \frac{x I}{2\pi r^2} \longrightarrow (5)$$

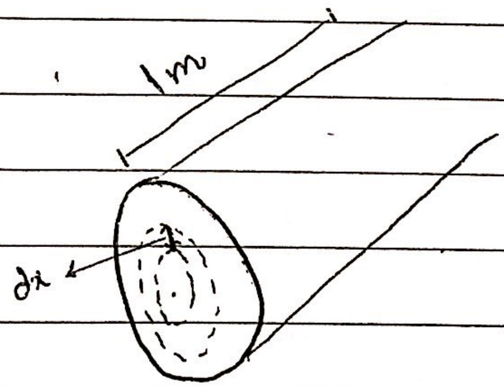
for non-magnetic Material :-

$$B_x = \mu_0 H_x$$

$$B_x = \frac{x I}{2\pi r^2} \mu_0 \longrightarrow (6) \qquad \mu_0 = 4\pi \times 10^{-7} \ H/m$$

Area

$$d\phi_x = B_x \, 1 \cdot dx \cdot 1$$



$$d\phi_x = \frac{x I}{2\pi r^2} \mu_0 \, dx \longrightarrow (7)$$

* note :- Only a fraction $\frac{\pi x^2}{\pi r^2}$ of a total Current is linked by the flux $d\lambda_x = \left(\frac{x^2}{r^2}\right) d\phi_x$

$$\cancel{\frac{xI}{2\pi r^2}\mu_0} \qquad d\lambda_x = \left(\frac{x^2}{r^2}\right) \frac{xI}{2\pi r^2} \mu_0 \, dx \rightarrow \#$$

total flux Linkegen

$$\lambda_{int} = \int_0^r \frac{\mu_0 I}{2\pi r^4} x^3 \, dx = \frac{\mu_0 I}{2\pi r^4} \left.\frac{x^4}{4}\right|_0^r$$

$$\lambda_{int} = \frac{\mu_0 I}{8\pi} \text{ web/m}$$

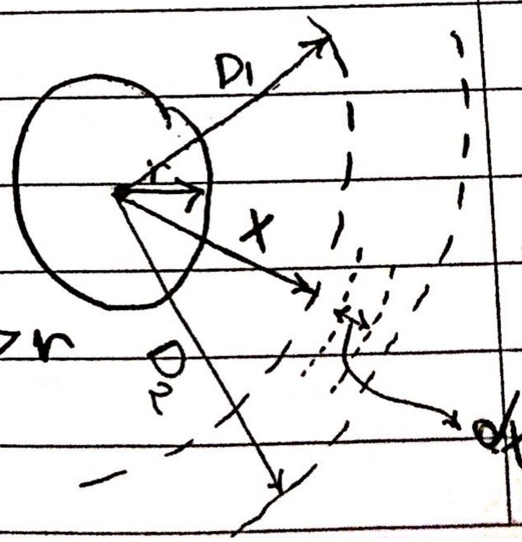
$$\therefore L_{int} = \frac{\lambda_{int}}{I} = \frac{\mu_0}{8\pi} = \frac{4\pi \times 10^{-7}}{8\pi} =$$

$$\boxed{L_{int} = \frac{1}{2} \times 10^{-7} \text{ H/m}} \rightarrow \#$$

the internal inductance of the Conductor is independent of the Conductor Radis (r).

* inductance due to external flux linkeges (L_{ext}) :-

from (3)



$$H_x = \frac{I}{2\pi x}$$

$$B_x = \mu_0 H_x = \mu_0 \frac{I}{2\pi x} \qquad x > r$$

all Current (I) is linked by the flux

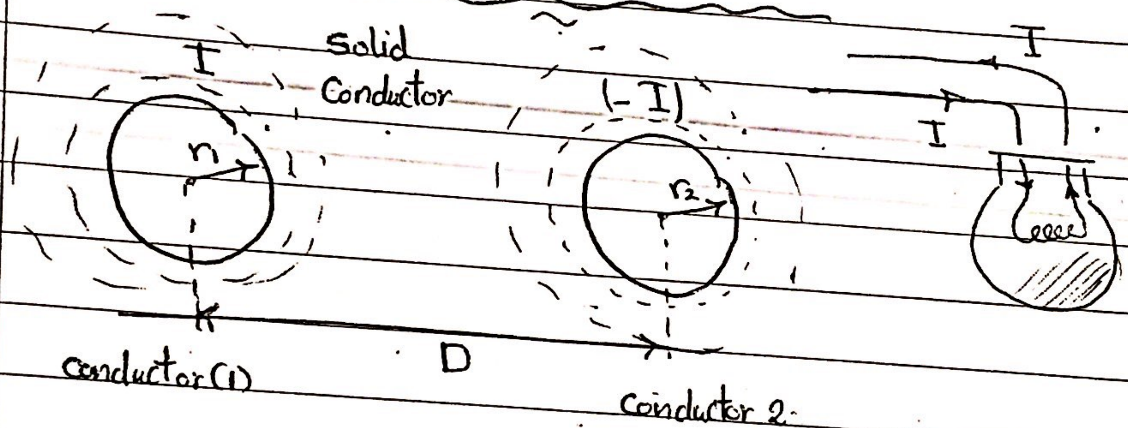
$$d\lambda_x = d\phi_x$$

$$= B_x\, dx \cdot 1 = \frac{\mu_0 I}{2\pi x} dx$$

$$\lambda_x = \frac{\mu_0 I}{2\pi}\int_{D_1}^{D_2} \frac{1}{x} dx = 2\times10^{-7} \ln \frac{D_2}{D_1} \text{ web/m}$$

$$\boxed{L_{ext} = 2\times10^{-7} \ln \frac{D_2}{D_1} \quad H/m} \longrightarrow \#$$

- inductance of a single-Phase Line :- 2015 13/19



cond # 1

$$L_{1int} = \frac{1}{2}\times10^{-7} \quad H/m$$

$$L_{1ext} = 2\times10^{-7} \ln \frac{D_2}{D_1} = 2\times10^{-7} \ln \frac{D_2}{r_1}$$

$$L_1 = L_{int} + L_{ext} = \frac{1}{2}\times10^{-7} + 2\times10^{-7} \ln \frac{D_2}{r_1}$$

$$= 2\times10^{-7}\left(\frac{1}{4} + \ln \frac{D_2}{r_1}\right)$$

$$= 2\times10^{-7}\left(\ln e^{1/4} + \ln \frac{1}{r_1} + \ln \frac{D}{1}\right)$$

0.01

$$= 2\times10^{-7}\left(\ln\frac{1}{r_1 e^{-1/4}} + \ln\frac{D}{1}\right)$$

$$r_1' = r_1 \cdot e^{-1/4} = 0.7788\, r_1$$

$$L_1 = 2\times10^{-7} \ln\frac{D}{r_1'} \quad H/m$$

Cond # 2

$$L_2 = 2\times10^{-7} \ln\frac{D}{r_2'}$$

if $r_1 = r_2 = r$

$$L_1 = L_2 = 2\times10^{-7} \ln\frac{D}{r'} \quad H/m$$

$$L_1 = L_2 = L = 0.2 \ln\frac{D}{r'} \quad mH/km$$

$r' = r\, e^{-1/4}$ = self gemetrical mean distance (Radies)

≡ GMR ∴ D_s

$$L = 0.2 \ln\frac{D}{r'} \; (mH/km)$$ in for One Conductor

∴ for the Complete Circuit of single Phase Line

$$L = L_1 + L_2 = 2L$$

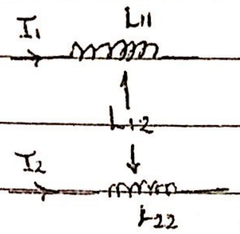
$$L = 4\times10^{-7} \ln\frac{D}{r'} \; (H/m)$$

$$L = 0.4\times10^{-7} \ln\frac{D}{r'} \; (mH/km)$$

* flux Linkges in terms of self and mutual inductance ...

$$\lambda_1 = L_{11} I_1 + L_{12} I_2$$

$$\lambda_2 = L_{21} I_1 + L_{22} I_2$$



• $I_1 = -I_2$, $I_2 = -I_1$

$$\lambda_1 = (L_{11} - L_{12}) I_1$$

$$\lambda_2 = (-L_{21} + L_{22}) I_2$$

$$L = \frac{\lambda}{I}$$

$$L_1 = \frac{\lambda_1}{I_1} = \underbrace{L_{11}}_{\text{self}} - \overbrace{L_{12}}^{\text{mutual}} = 2\times10^{-7} \ln \frac{D}{r'} = 2\times10^{-7}\left(\ln D + \ln \frac{1}{r_1'}\right)$$

$$L_2 = \frac{\lambda_2}{I_2} = -L_{21} + L_{22}$$

$$L_{11} = 2\times10^{-7} \ln \frac{1}{r_1'}$$

$$L_{12} = 2\times10^{-7} \ln \frac{1}{D}$$

$$L_2 = \frac{\lambda_2}{I_2} = -L_{21} + L_{22} = 2\times10^{-7} \ln \frac{D}{r_2'}$$

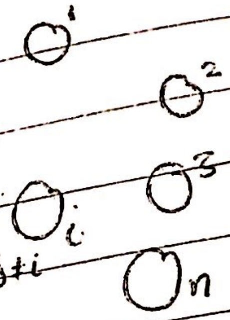
$$L_{22} = 2\times10^{-7} \ln \frac{1}{r_2'}$$

$$L_{21} = L_{12} = 2\times10^{-7} \ln \frac{1}{D}$$

$(I_1, I_2 \dots I_n)$

for (n) Conductor $I_1, I_2 \dots I_n$

such that $I_1 + I_2 + I_3 \dots I_n = 0$



for Conductor i :-

$\lambda_i = L_{ii} I_i + \sum_{j=1}^{n} L_{ij} I_j \quad i \neq j$

or $\lambda_i = 2\times10^{-7} \left(I_i \ln \frac{1}{r_i'} + \sum_{j=1}^{n} I_j \ln \frac{1}{D_{ij}} \right) j \neq i$

* inductance of Three Phase transmission Lines :-

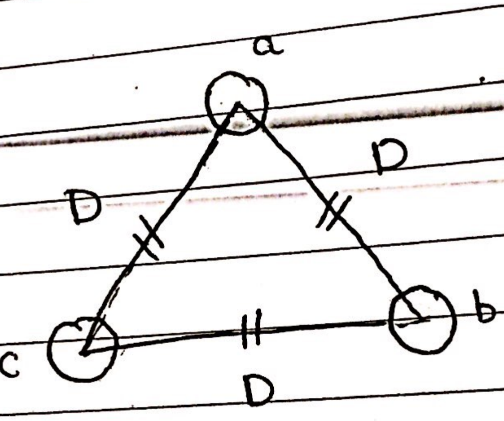
① symetrical spacing

في الطبيعة غير موجودة أو نادرة جداً

for 1m of the Line

we Assume balance 3-Phase Currents :-

$I_a + I_b + I_c = 0$



Flux Linkage

$\cancel{\lambda_a = 2\times10^{-7} (\ln I_a \ln \frac{1}{r'})}$

* Single	* Three Phase
* $L = L_a + L_b$	* $L = L_a = L_b = L_c$

flux Linkage

$$\lambda_a = 2\times10^{-7} \left(I_a \ln \frac{1}{r'} + I_b \ln \frac{1}{D} + I_c \ln \frac{1}{D} \right)$$

$I_b + I_c = -I_a$

28/3/2017

$$\lambda_a = 2\times10^{-7}\left(I_a \ln\frac{1}{r'} - I_a \ln\frac{1}{D}\right)$$

$$\boxed{\ln\frac{1}{D}(I_a+I_b) = -I_a \ln\frac{1}{D}}$$

$$\boxed{\lambda_a = 2\times10^{-7}\ I_a \ln\frac{D}{r'} \quad H/m} \longrightarrow \#$$

$$\boxed{\begin{aligned} \therefore \lambda_b &= 2\times10^{-7}\ I_b \ln\frac{D}{r'} \\ \lambda_c &= 2\times10^{-7}\ I_c \ln\frac{D}{r'} \end{aligned}}$$

$$L_a = \frac{\lambda_a}{I_a} = 2\times10^{-7} \ln\frac{D}{r'} \quad H/m$$

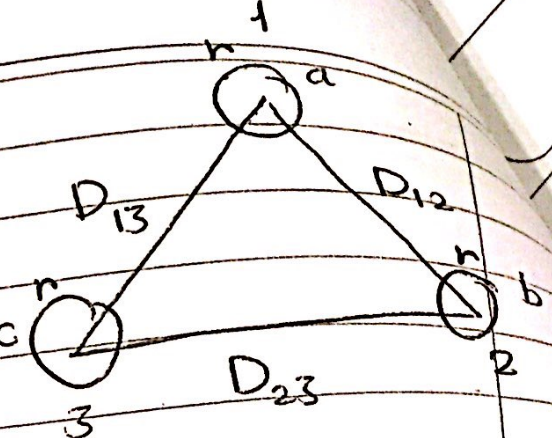
$r' \longrightarrow$ GMR: Saible $= r e^{-1/4}$; Strand = جدول

$$L = L_a = L_b = L_c = H/m/phase$$

$$L = 0.2 \ln\frac{D}{r'} \quad mH/km/phase$$

* for Solid Conductor $r' = 0.7788\, r$
* // Strand // $\rightarrow$ use table (GMR) or (Ds)

② a-symmetrical spacing :-
(non-)



$$\lambda_i = 2\times10^{-7}\left(I_i \ln\frac{1}{r_i'} + \Sigma I_j \ln\frac{1}{D_{ij}}\right)$$

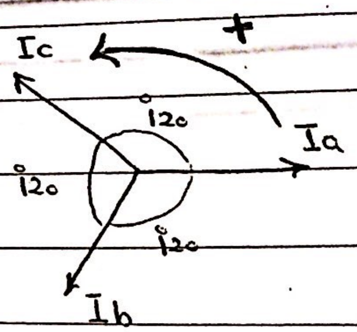
$$\lambda_a = 2\times10^{-7}\left(I_a \ln\frac{1}{r'} + I_b \ln\frac{1}{D_{12}} + I_c \ln\frac{1}{D_{13}}\right)$$

$$\lambda_b = 2\times10^{-7}\left(I_a \ln\frac{1}{D_{12}} + I_b \ln\frac{1}{r'} + I_c \ln\frac{1}{D_{23}}\right)$$

$$\lambda_c = 2\times10^{-7}\left(I_a \ln\frac{1}{D_{13}} + I_b \ln\frac{1}{D_{23}} + I_c \ln\frac{1}{r'}\right)$$

$I_a \angle 120^\circ = I_c$

$I_a \angle 240^\circ = I_b$



$a = 1\angle 120^\circ$, $a^2 = 1\angle 240^\circ$

$a^3 = 1\angle 360^\circ$

$$\lambda_a = 2\times10^{-7}\left(I_a \ln\frac{1}{r'} + I_a a^2 \ln\frac{1}{D_{12}} + a I_a \ln\frac{1}{D_{13}}\right)$$

$$L_a = \frac{\lambda_a}{I_a} = 2\times10^{-7}\left(\ln\frac{1}{r'} + a^2 \ln\frac{1}{D_{12}} + a \ln\frac{1}{D_{13}}\right)$$

$a + a^2 = -1$

$\angle 120 + \angle 240 = -1$

$L_a \neq L_b \neq L_c$

$$L_{avg} = \frac{L_a + L_b + L_c}{3} = \frac{2\times10^{-7}}{3}\left(3\ln\frac{1}{r'} - \ln\frac{1}{D_{12}} - \ln\frac{1}{D_{13}} - \ln\frac{1}{D_{23}}\right)$$

$$\frac{1}{3}\ln\frac{1}{D} = \ln\left(\frac{1}{D}\right)^{1/3} = \ln\frac{1}{D^{1/3}}$$

$$L_{avg} = 2\times10^{-7}\left(\ln\frac{1}{r'} - \ln\frac{1}{(D_{12}\,D_{23}\,D_{13})^{1/3}}\right)$$

$$L_{avg} = 2\times10^{-7}\ln\frac{(D_{12}\,D_{23}\,D_{13})^{1/3}}{r'}$$

$$L_{avg} = 2\times10^{-7}\ln\frac{GMD}{r'} \quad H/m$$

$$GMD = \sqrt[3]{D_{12}\,D_{23}\,D_{13}}$$ "Geometrical mean distance."

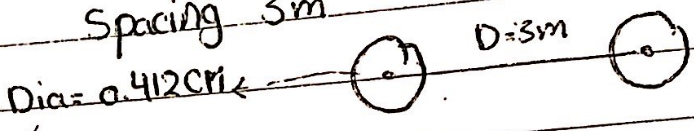
$$L = 0.2\ln\frac{GMD}{r'} \quad mH/Km/phase$$

$$L = 0.2\ln\frac{GMD}{GMR}$$

Ex # 1 :-

① Single-Phase Line :-

The Conductor of a single Phase Line, 60 HZ, is a ~~sold~~ Solid round aluminum Conductor, Spacing 3m



Determine the inductance of the Line in (mH/mile) How much of this inductance is due to internal flux-linkage neglect skin-Effect.

Solution

$$L = 2\times10^{-7} \ln \frac{D}{r'} \quad (H/m)$$

$$r = \frac{0.412\ cm}{2} = 0.206\ cm.$$

$$r' = e^{-1/4} \cdot r = 0.206 \times 0.7788\ cm$$

$$L = 2\times\left[2\times10^{-7} \ln \frac{300\,cm}{0.206\times0.7788\,cm} \cdot \frac{\cancel{H}}{\cancel{m}} \cdot \left(\frac{10^{3}\,mH}{1\,\cancel{H}}\right)\left(\frac{1609\,\cancel{m}}{1\,mil}\right)\right]$$

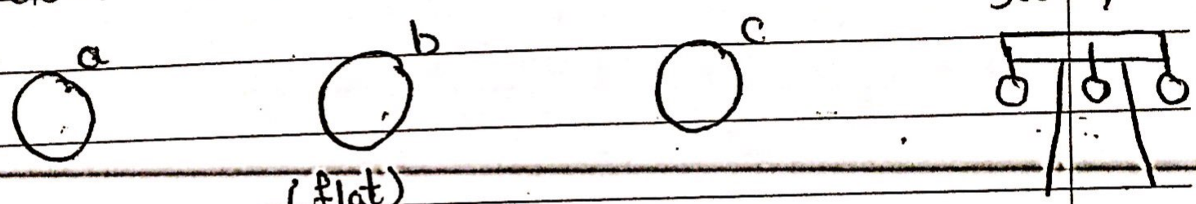
$$L = 4.85\ mH/mile$$

$$L_{in} = 2 \times \left(\frac{1}{2} \times 10^{-7} \times 10^{3} \times 1609 \ mH/mile \right)$$

$$L_{in} = 0.16 \ mH/mile$$

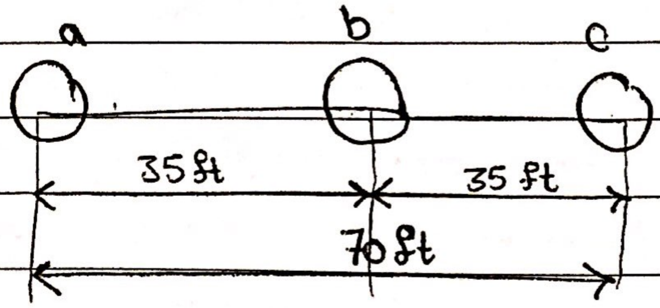
Ex : #2 3phase Line

A 500-kv, 3-phase (ph) transposed Line Composed of One (ACSR) (1272000 cmil)



* (45/7) → bittern Conductor/ph
  * horizontal spacing
  * Diam = 1.345 inch
  * GMR = 0.5328 inch

Calculate the inductance/ph/km.



Solution

$$L = 2 \times 10^{-7} \ln \frac{GMD}{GMR}$$

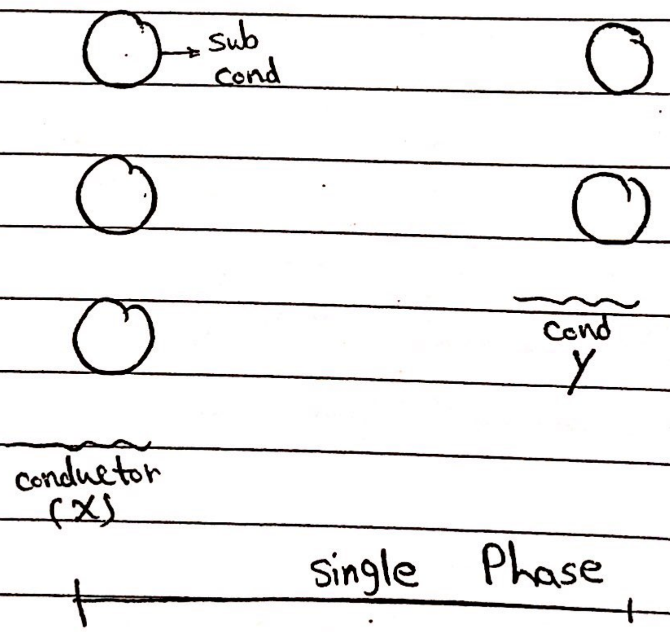
$$GMD = \sqrt[3]{D_{12} \cdot D_{13} \cdot D_{23}}$$

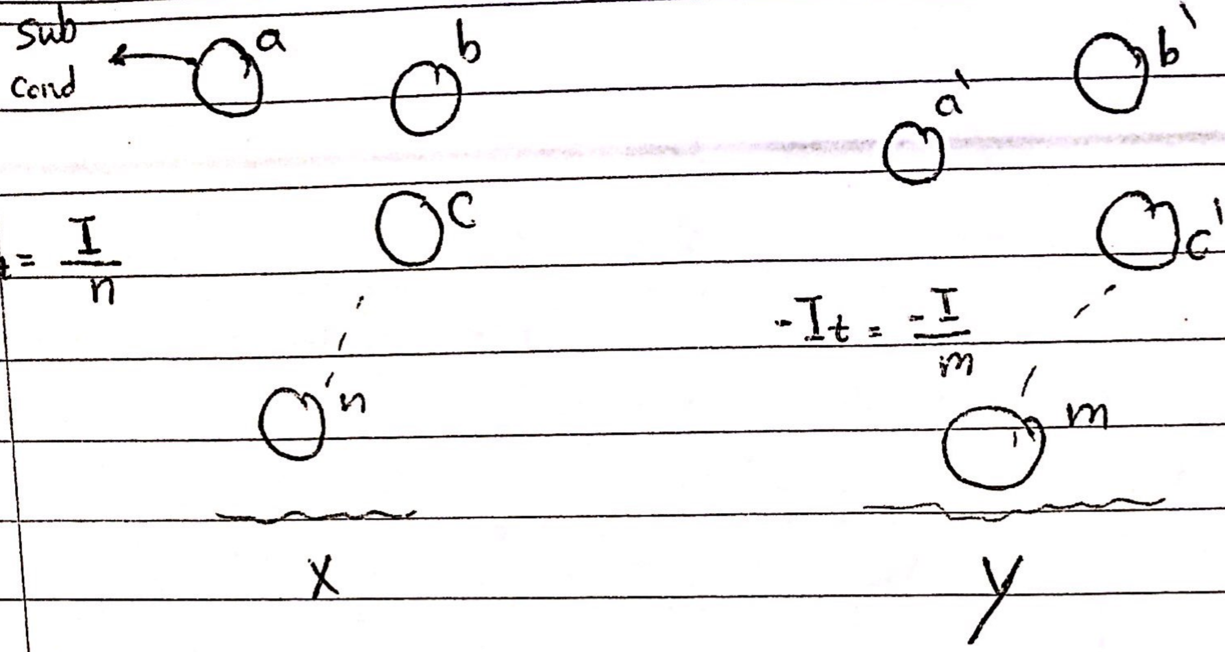
$$GMD = \sqrt[3]{(35)\,(35)\,(70)} = 44.097 \text{ ft}$$

$$L = 2 \times 10^{-7} \ln \frac{44.097 \text{ ft} \times 12 \text{ inch}}{0.5328 \text{ inch}}$$

$$L = 0.2 \ln \frac{44.097 \text{ ft} \times 12 \text{ inch}}{0.5328 \text{ inch}} = 1.38 \text{ mH/km}$$

* inductance of Composite Conductors :-





$$I_t = \frac{I}{n} \qquad -I_t = \frac{-I}{m}$$

$$\lambda_i = 2\times10^{-7}\left(I_i \ln\frac{1}{r_i'} + \sum_{j=1}^{n} I_j \ln\frac{1}{D_{ij}} \right) \quad j \neq i$$

$$\lambda_a = 2\times10^{-7}\left(\frac{I}{n}\ln\frac{1}{r_x'} + \frac{I}{n}\ln\frac{1}{D_{ab}} + \frac{I}{n}\ln\frac{1}{D_{ac}} + \cdots + \frac{I}{n}\ln\frac{1}{D_n} \right) - 2\times10^{-7}\left(\frac{I}{m}\ln\frac{1}{D_{aa'}} + \frac{I}{m}\ln\frac{1}{D_{ab'}} + \cdots + \frac{I}{m}\ln\frac{1}{D_{am}} \right)$$

$$\lambda_a = 2\times10^{-7}\, I \ln\left[\frac{\sqrt[m]{D_{aa'}\ D_{ab'}\ D_{ac'} \cdots D_{am}}}{\sqrt[n]{r_x'\ D_{ab}\ D_{ac} \cdots D_{an}}} \right]$$

$$L_a = \frac{\lambda_a}{I/n} \rightarrow I_a = \frac{I}{n}$$

$$L_a = n\, 2\times10^{-7} \ln \frac{\sqrt[m]{D_{aa'} \cdot D \ldots}}{\sqrt[n]{\ldots}}$$

$$L_{n} = \frac{\lambda}{I/n} = n\, 2\times10^{-7} \ln \frac{\sqrt[m]{D_{na'} D_{nb'} \cdots D_{nm}}}{\sqrt[n]{r_x' D_{na} D_{nb} \cdots}}$$

$$L_{avg} = \frac{L_a + L_b + \cdots + L_n}{n}$$

$$\therefore L_x = \frac{L_{avg}}{n}$$

ملاحظة:
لأنهم متوازيات
بنطلع (L)
الكلية

$$L_x = \frac{L_a + L_b + \cdots L_n}{n^2}$$

$$L_x = 2\times10^{-7} \ln \frac{GMD}{GMR} \quad H/m$$

هذا كافي لل
(y,x)

$$GMD = \sqrt[mn]{(D_{aa'})(D_{ab'} \cdots D_{am})(D_{bb'} D_{ba'} \cdots D_{bm})(D_{ca'} \cdots)(D_{na'} \cdots D_{bn} \cdots D_{mn})}$$

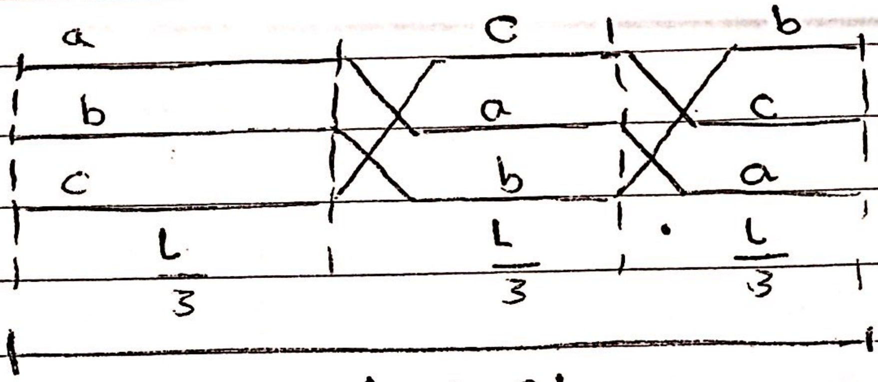
$$GMR_x = \sqrt[n^2]{(D_{aa} D_{ab} D_{ac} \cdots D_{an})(D_{ba} D_{bb} D_{bc} \cdots D_{bn})(D_{ca} D_{cb} D_{cc} \cdots D_{cn})}$$

$$GMR_y = \sqrt[m^2]{(D_{a'a'} D_{a'b'} D_{a'm})(D_{b'a'} D_{b'b'} \cdots D_{b'm}) \cdots}$$

$$D_{aa} = D_{bb} = D_{cc} = \cdots D_{nn} = r'_x$$

$$D_{a'a'} = D_{b'b'} = D_{c'c'} = \cdots D_{mm} = r'_y$$

* Transposition



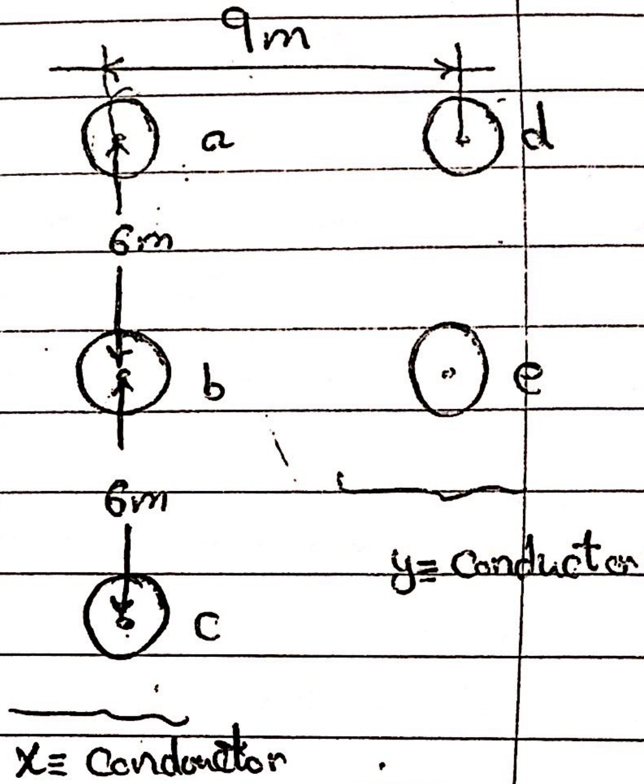
1 Cycle

2015 / 3 / 26

* Ex: #1 Composite Counductors

x: solid $r = 0.25$ cm
y: solid $r = 0.5$ cm

for the single-Phase line shown, find the inductance of the line in (H/m) and (mH)/(mi)



Solution

$$L_x = 2\times10^{-7} \ln \frac{GMD}{GMR_x}$$

$$L_y = 2\times10^{-7} \ln \frac{GMD}{GMR_y}$$

$$L_{in} = L_x + L_y$$

$D_{ad} = 9m = D_{be}$

$D_{ae} = \sqrt{9^2+6^2} = 3\sqrt{13} = D_{bd} = D_{ce}$

$D_{cd} = \sqrt{9^2+12^2} = 15$ cm

$$GMD = \sqrt[6]{D_{ad}\cdot D_{ae}\cdot D_{bd}\cdot D_{be}\cdot D_{cd}\cdot D_{ce}} = 10.743\,m$$

$$GMR_x = \sqrt[9]{(D_{aa}\cdot D_{ab}\cdot D_{ac})(D_{ba}D_{bb}D_{bc})(D_{ca}D_{cb}D_{cc})}$$

$$= \sqrt[9]{(r')^3 (6)^4 (12)^2} = \sqrt[9]{\left(0.7788\left[0.25\times10^{-2}\right]\right)^3 (6)^4 (12)^2}$$

$$GMR_x = 0.481 \text{ m}$$

$$GMR_y = \sqrt[4]{D_{dd} \cdot D_{de}\, D_{ed}\, D_{ee}} = \sqrt[4]{r_y'^2 \; (6)^2}$$

$$= \sqrt[4]{\left[0.7788\times(0.5\times10^{-2})\right]^2 \; (6)^2}$$

$$GMR_y = 0.153 \text{ m}$$

① $$L_x = 2\times10^{-7} \ln \frac{10.743}{0.481} = 6.212\times10^{-7} \text{ H/m}$$

$$L_y = 2\times10^{-7} \ln \frac{10.743}{0.153} = 8.503\times10^{-7} \text{ H/m}$$

② $$L_x = 6.212\times10^{-7} \frac{H}{m} \cdot \frac{10^3 mH}{\cancel{H}} \cdot \frac{1609 \text{ m}}{\text{mil}} = \quad '' \quad \text{mH/mil}$$

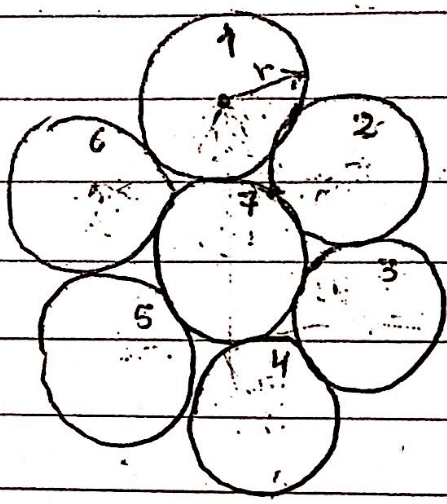
$$L_y = 8.503\times10^{-7} \frac{H}{m} \cdot \frac{10^3 mH}{H} \cdot \frac{1609 \text{ m}}{\text{mil}} = \quad '' \quad \text{mH/mil}$$

$$L = L_x + L_y = 14.715\times10^{-7} \text{ H/m}$$

$$L = 14.715\times10^{-7} \frac{H}{m} \times \frac{10^3 mH}{H} \times \frac{1609 \text{ m}}{\text{mil}} = 2.37 \frac{mH}{mil}$$

Ex: #2

– A stranded Conductor has (7) strands as shown, each strand has Radius (r) Determine the (GMR) of the Conductor in terms of (r).



$$GMR = \sqrt[49]{(D_{11} D_{12} D_{13} D_{14} D_{15} D_{16} D_{17})^6} \text{ - - - -}$$

$D_{11} = D_{22}\ D_{33} = D_{44} = D_{55} = D_{66} = D_{77} = r' = 0.7788r$

$D_{12} = D_{16} = D_{17} = 2r$

$D_{13} = \sqrt{D_{14}^2 - D_{34}^2} = \sqrt{(4r^2) - (2r)^2} = \sqrt{(16-4)r^2} = 2\sqrt{3}\ r.$

$D_{13} = 2\sqrt{3}r - D_{15}$

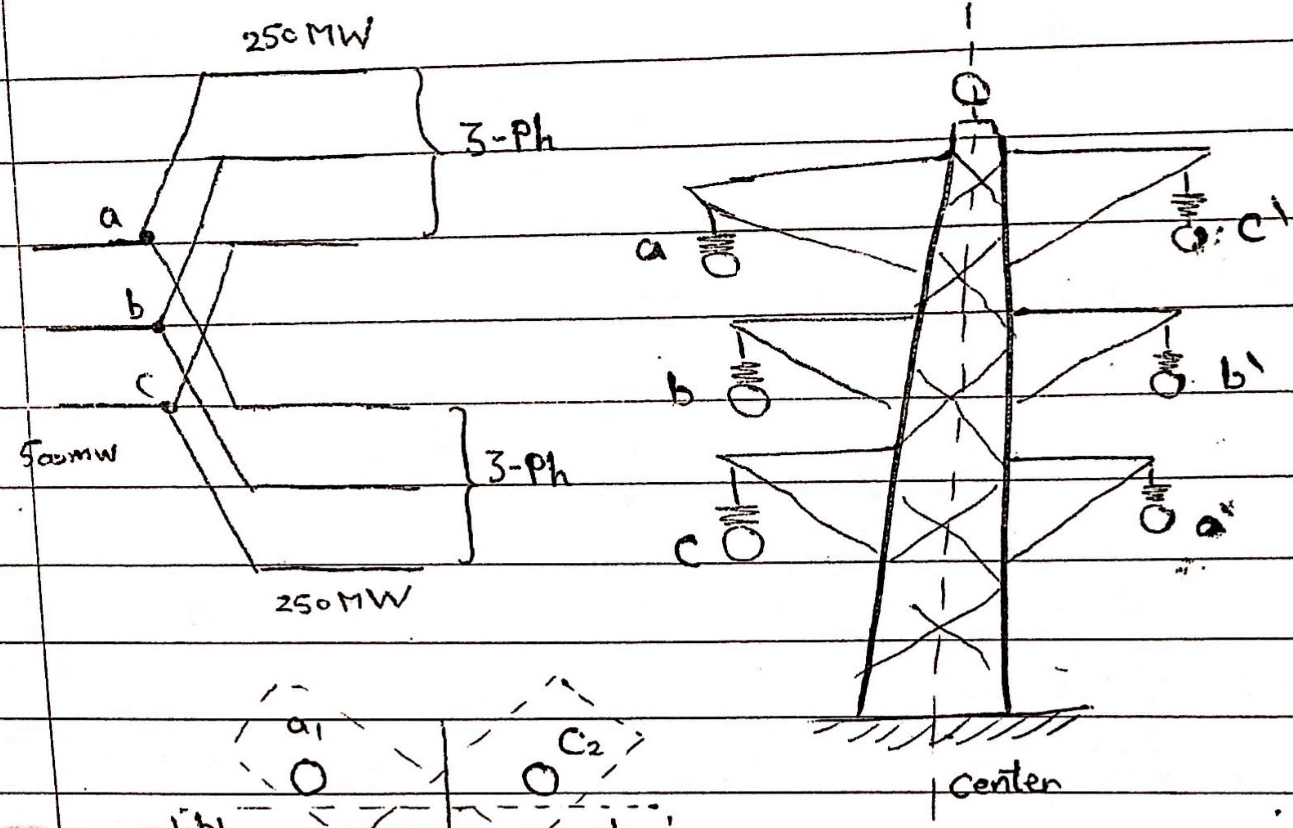
$D_{14} = 4r$

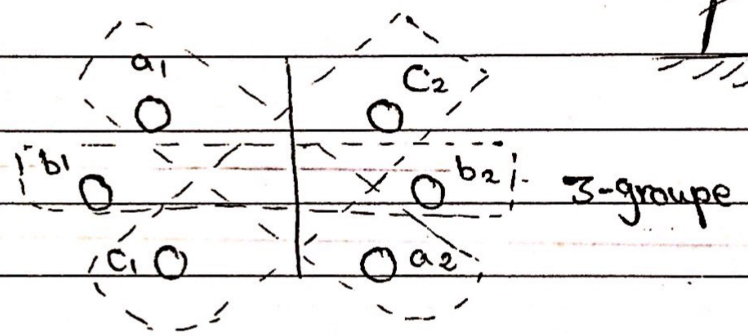
$D_{34} = 2r$

$$GMR = \sqrt[49]{\left[(0.7788r)(2r)^3(2\sqrt{3}\ r)^2(4r)\right]^6 \left[(0.7788r\,(2r)^6)\right]}$$

$GMR = 2.176\ r$

* inductance of double-Circuit line (3-Phase):





* to find GMD :-

① find (GMD) between any two groups.

$$GMD_{AB} = \sqrt[4]{D_{a_1b_1} D_{a_1b_2} D_{a_2b_1} D_{a_2b_2}}$$

$$GMD_{BC} = \sqrt[4]{D_{b_1c_1} D_{b_1c_2} D_{b_2c_1} D_{b_2c_2}}$$

$$GMD_{AC} = \sqrt[4]{D_{a_1c_1} D_{a_1c_2} D_{a_2c_1} D_{a_2c_2}}$$

$$GMD_{equivilent} = \sqrt[3]{(GMD_{AB})(GMD_{BC})(GMD_{AC})}$$

② find GMR

$$GMR_A = \sqrt[4]{D_{a_1a_1} \, D_{a_1a_2} \, D_{a_2a_1} \, D_{a_2a_2}}$$

$$r' = D_{a_1a_1} = D_{a_2a_2} = D_s$$

$$GMR_A = \sqrt[4]{(D_s \, D_{a_1a_2})^2} = \sqrt{D_s \, D_{a_1a_2}}$$

$$GMR_A = \sqrt{D_s \, D_{a_1a_2}}$$

$$GMR_B = \sqrt{D_s \, D_{b_1b_2}}$$

$$GMR_C = \sqrt{D_s \, D_{c_1c_2}}$$

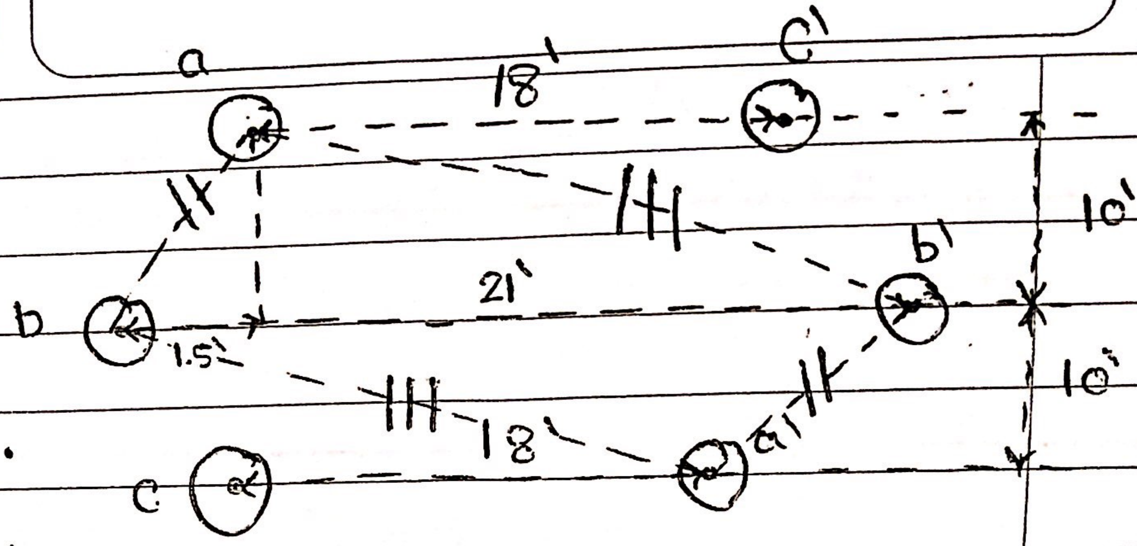
$$GMR_{equ} = \sqrt[3]{(GMR_A)(GMR_B)(GMR_C)}$$

③ $L = 2\times10^{-7} \ln \frac{GMD_{equ}}{GMR_{equ}} \left(\frac{H}{m}\right)$

* Ex :- #3

inductance of a (3-Ph) Double Circuit Line has (300,000 (CMil)) (26/7) "ostrich" Conductors arranged as shown find the (60-Hz) inductive Reactance of the Line

feet = 1'
inch = 1"



$$GMD_{AB} = \sqrt[4]{(10.1 \times 21.9)^2} = 14.88'$$

$$D_{ab} = D_{a'b'} = \sqrt{1.5^2 + 1.2^2} = 10.1'$$

$$D_{ab'} = D_{a'b} = \sqrt{19.5^2 + 10^2} = 21.9'$$

$$GMD_{BC} = GMD_{AB}$$

$$GMD_{AC} = \sqrt[4]{D_{ac} \cdot D_{ac'} \cdot D_{a'c} \cdot D_{a'c'}} = 18.97'$$

$$GMR_A = \sqrt{D_s \, D_{aa'}} = \sqrt{0.0229 \times 26.9} = 0.785'$$

$$GMR_B = \sqrt{0.0229 \times 21} = 0.693'$$

$$GMR_C = 0.785'$$

$$GMR_{equ} = \sqrt[3]{(0.785)^2 \times 0.693} = 0.753'$$

$$L = 2 \times 10^{-7} \ln \frac{16.1}{0.753} = 6.13 \times 10^{-7} \left(\frac{H}{m}\right)$$

$X_L = \omega L = 2\pi f L$

$= 2\pi \times (60\,Hz)(6.13 \times 10^{-7} \times 10^{3}) = 0.23\ \Omega/Km$

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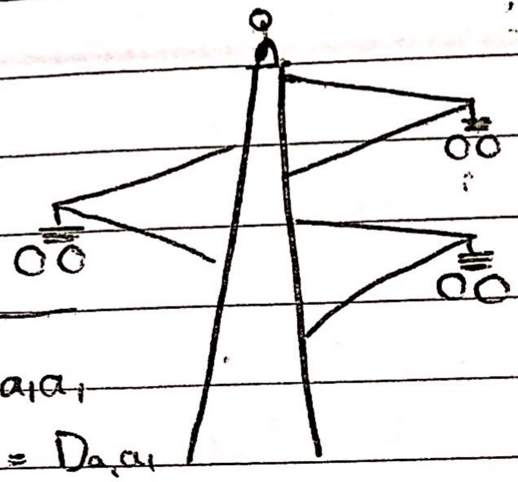
* Bundle Conductors :-



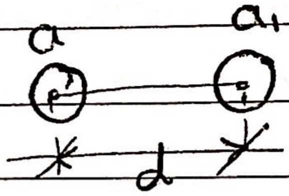
$$L = 0.2 \ln \frac{GMD}{GMR} \quad mH/Km$$

$n = 2$

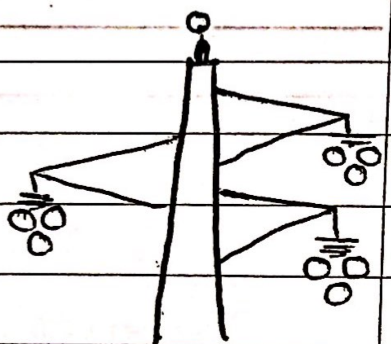
$$GMR_{(b)} = \sqrt[4]{D_{aa}\, D_{aa_1}\, D_{a_1a}\, D_{a_1a_1}}$$

$D_s = D_{aa}$ $\quad D_s = D_{a_1a_1}$

$$= \sqrt[4]{D_s^2\, D_{a_1a}^2}$$



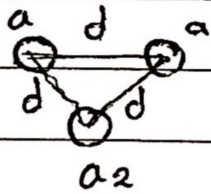
$$GMR_{(b)} = \sqrt{D_s d}$$

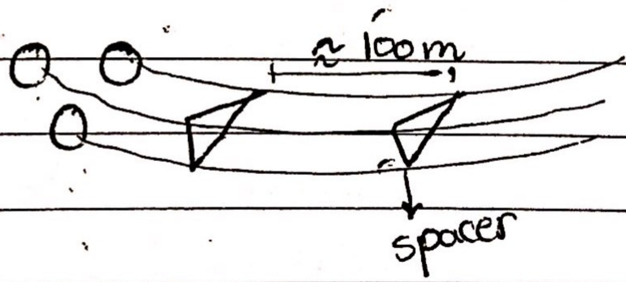


$$GMR_{(b)} = \sqrt[9]{(D_{aa_1}\, D_{aa}\, D_{aa_2})^3}$$

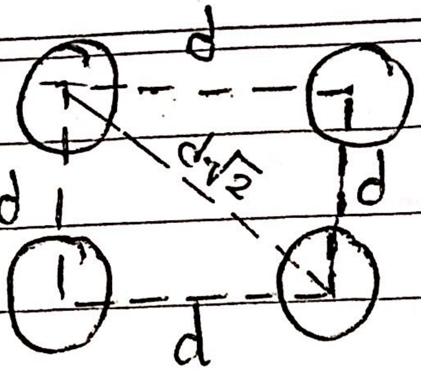
$$= \sqrt[9]{(D_s d^2)^3}$$

$$= \sqrt[3]{D_s d^2}$$

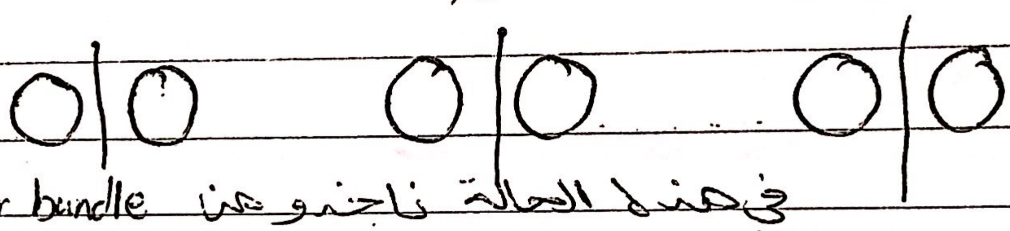




$$GMR(b) = \sqrt[16]{\left(D_s\, d\, (\sqrt{2}\,d)\, d\right)^4}$$



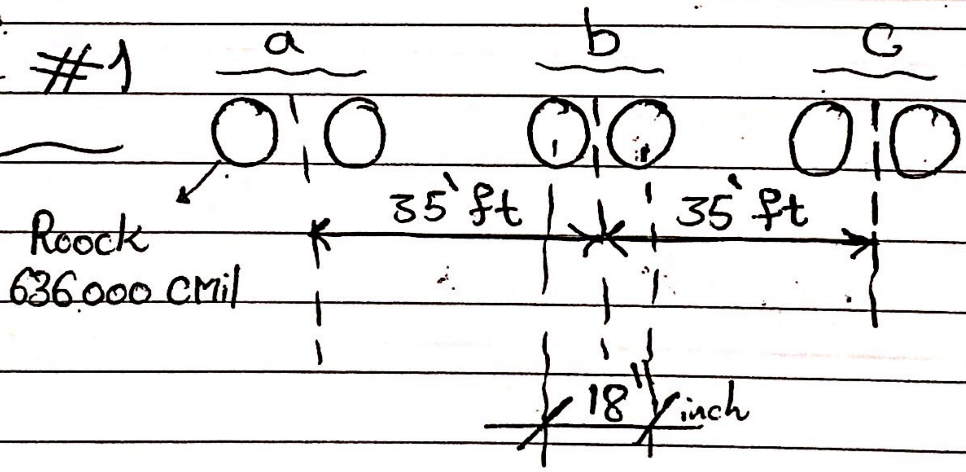
$$GMR(b) = 1.09\sqrt[4]{D_s\, d^3}$$



في هذه الحالة ناخذو من Center bundle
إلى Center bundle وليس من center cond

$p \propto \frac{1}{x}$ نقدر نرفع الـ (power)

* **Ex :- #1**



$$GMR = 0.3924''\ \text{inch}$$

$$GMR(b) = \sqrt{0.3924 \times 18} = 2.657\ \text{inch}$$

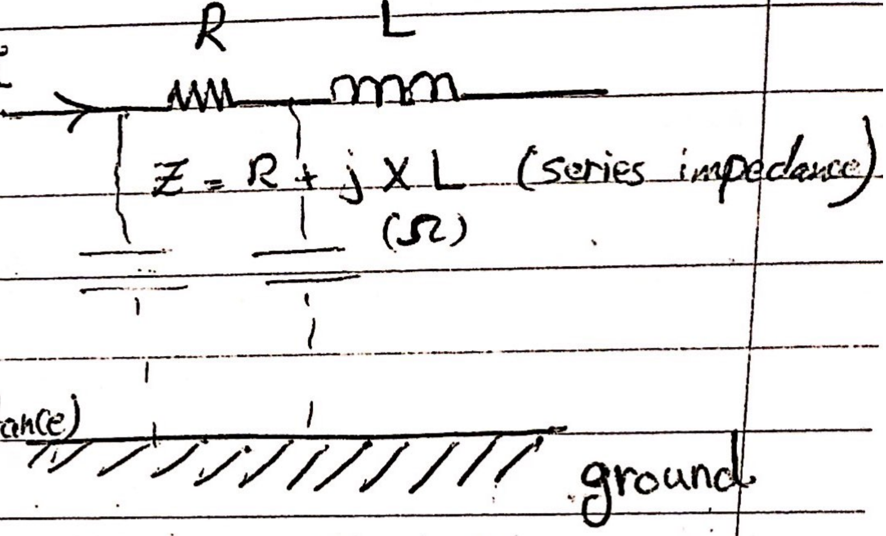
$$GMR(b) = \frac{2.657}{12} = 0.2214\ \cancel{\text{inch}}\ \text{ft}$$

$GMD = \sqrt[3]{35 \times 35 \times 70} = 44 \text{ ft}$

$L = 0.2 \ln \frac{44.097}{0.22147} = 1.0588 \text{ mH/km}$

% decrease in L = 23.3%

Capacitance (C) :-



$Y = G + jB$ (S)

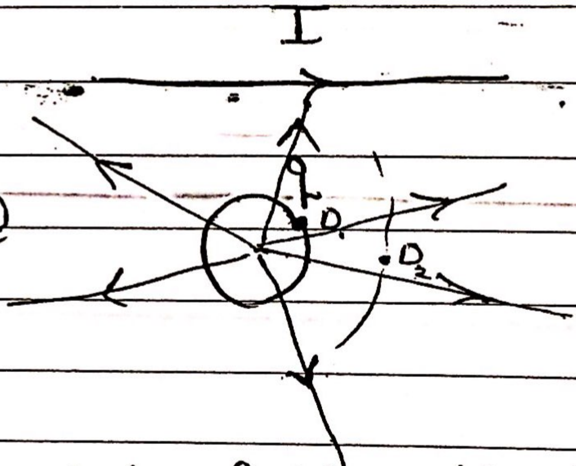
$= G + j\omega C$

$G =$ [illegible]

$Y = j\omega C$ (shunt admittance)

$$\boxed{C = \frac{q}{V}}$$

$\phi = Q$



Electric field Lines.

$E = \frac{D}{\varepsilon_0}$

$E =$ electric field intensity

$D =$ flux desity

$\varepsilon_0 =$ permativity free space

8.85×10^{-12}

$D = \frac{q}{A} = \frac{q}{(2\pi x)(1)} = \cancel{\frac{q}{2}}$

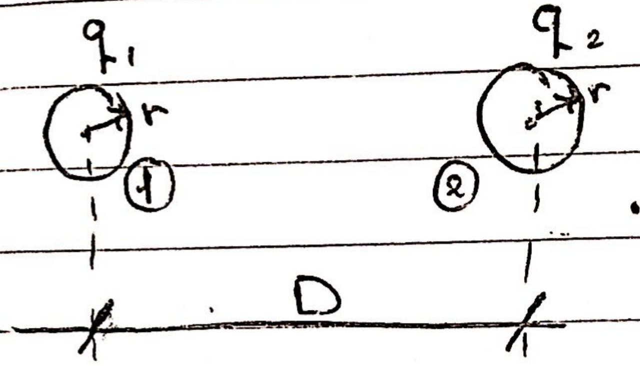
$E = \frac{q}{2\pi(x)\varepsilon_0}$

$$V_{12} = \int_{D_1}^{D_2} E \cdot dx = \int_{D_1}^{D_2} \frac{q}{2\pi\epsilon_0 x}\, dx = \frac{q}{2\pi\epsilon_0 \cancel{x}} \ln\frac{D_2}{D_1}$$

مانشيل x

Capacitance of single - Phase Lines :-

$$V_{12} = \frac{q}{2\pi\epsilon_0} \ln \frac{D_2}{D_1}$$



$$q_1 = -q_2$$

for (1m) of the line :-

$D >> r$

* Conductor # 1 :- (alone)

$$V_{12}(q_1) = V_{12} = \frac{q_1}{2\pi\epsilon_0} \ln \frac{D}{r} \rightarrow (q_1)$$

* Conductor # 2 :- (alone)

$$V_{21}(q_2) = \frac{q_2}{2\pi\epsilon_0} \ln \frac{D}{r}$$

$$V_{12}(q_2) = -V_{21}(q_2)$$

$$V_{12}(q_2) = \frac{q_2}{2\pi\epsilon_0} \ln \frac{r}{D}$$

using Soupre position :-

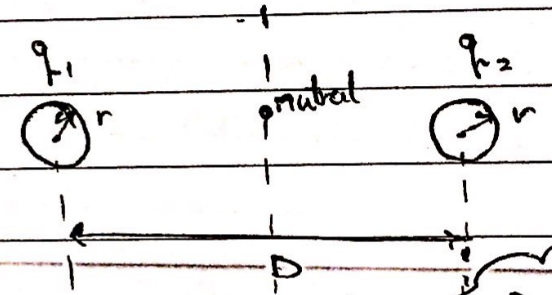
$$V_{12} = V_{12}(q_1) + V_{12}(q_2)$$

$$= \frac{q_1}{2\pi\epsilon_0} \ln \frac{D}{r} + \frac{q_2}{2\pi\epsilon_0} \ln \frac{r}{D}$$

Let $q_1 = -q_2 = q$

$$\boxed{V_{12} = \frac{q}{2\pi\epsilon_0} \ln \frac{D}{r}}$$

$$C_{12} = \frac{q}{V_{12}} \Rightarrow \boxed{C_{12} = \frac{\pi\epsilon_0}{\ln \frac{D}{r}} \ F/m}$$



$$C = \frac{q}{V}$$

ديما إلي بيهمني في power
بالنسبة لل nutral وليس
من Line لإلي Line او
conduc لإلي Conduc

$$C_n V_{12} = C_{12} V_{12}$$

$$C_n \frac{1}{2} \cancel{V_{12}} = C_{12} \cancel{V_{12}}$$

$$C_n = 2 C_{12}$$

$$\boxed{C_n = \frac{2\pi\epsilon_0}{\ln D/r} \ f/m}$$

$$= 2 \times \pi \times 8.85 \times 10^{-12} \times \frac{10^6 \mu F}{1 F} \cdot \frac{10^3 m}{1 Km}$$

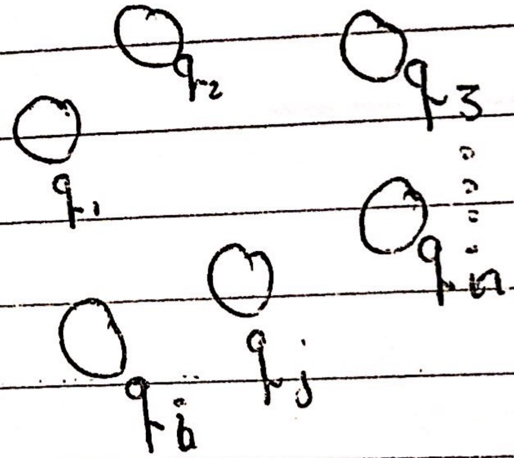
$$\boxed{C_n = C_o = \frac{0.0556}{\ln D/r} \ \mu F/Km}$$

note :-

① for L , $r' = e^{-1/4} r$

② for C , r = radius of conduc

* Potential difference in multi Conductor Configuration :-



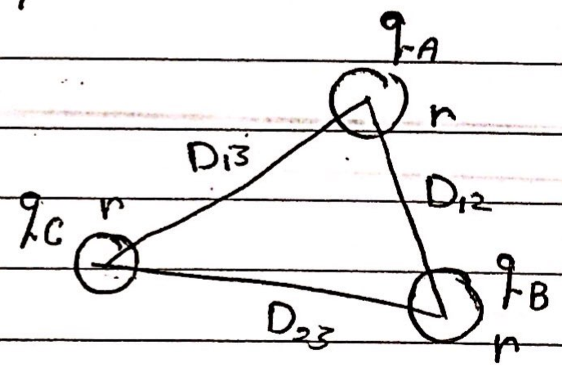
- (n) parallel conductance
- We Assume $q_1 + q_2 + \dots + q_n = 0$

$$\boxed{V_{ij} = \frac{1}{2\pi\epsilon_0} \sum_{k=1}^{n} q_k \ln \frac{D_{kj}}{D_{kj}}}$$

$$V_{12} = \frac{1}{2\pi\epsilon_0}\left(q_1 \ln \frac{D}{r} + q_2 \ln \frac{r}{D}\right) \checkmark$$

* Capacitance of 3-Phase Line :-

① non-symmetrical

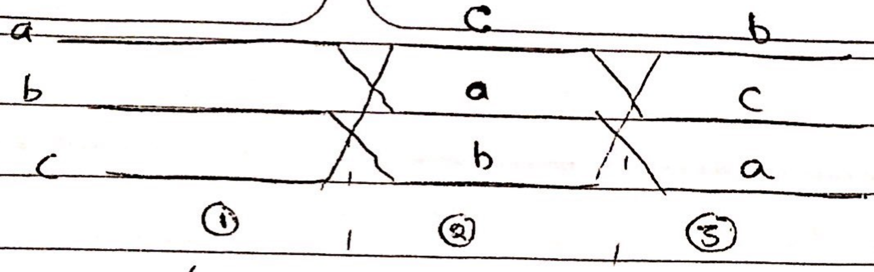


① for (1m) of the (3-Ph) line

$$q_A + q_B + q_C = 0$$

② ground Effect is neglected.

③ Assume tranposition.



(Transpostion Line).

* Calculate V_{AB}? stage (1)

$$V_{AB} = \frac{1}{2\pi\epsilon_0}\left[q_A \ln\frac{D_{12}}{r} + q_B \ln\frac{r}{D_{12}} + q_C \ln\frac{D_{23}}{D_{13}}\right]$$

* VAB stage (2)

$$V_{AB} = \frac{1}{2\pi\epsilon_0}\left[q_A \ln\frac{D_{23}}{r} + q_B \ln\frac{r}{D_{23}} + q_C \ln\frac{D_{13}}{D_{12}}\right]$$

* VAB stage (3)

$$V_{AB} = \frac{1}{2\pi\epsilon_0}\left[q_A \ln\frac{D_{13}}{r} + q_B \ln\frac{r}{D_{13}} + q_C \ln\frac{D_{12}}{D_{23}}\right]$$

* take Avrage Value (VAB).

$$V_{AB(avg)} = \frac{1}{3(2\pi\epsilon_0)}\left(q_A \ln\frac{D_{12}D_{23}D_{13}}{r^3} + q_B \ln\frac{r^3}{D_{12}D_{23}D_{13}} + \underbrace{q_C \ln\frac{\cancel{D_{23}}\,\cancel{D_{13}}\,\cancel{D_{12}}}{\cancel{D_{13}}\,\cancel{D_{12}}\,\cancel{D_{23}}}}_{Zero}\right)$$

$$V_{AB}(Avg) = \frac{1}{2\pi\epsilon_0}\left(q_A \ln\frac{\sqrt[3]{D_{12}D_{23}D_{13}}}{r} + q_B \ln\frac{r}{\sqrt[3]{D_{12}D_{13}D_{23}}}\right)$$

$$V_{AB(avg)} = \frac{1}{2\pi\epsilon_0}\left(q_A \ln\frac{GMD}{r} + q_B \ln\frac{r}{GMD}\right)$$

similary

$$U_{AC\,(avg)} = \frac{1}{2\pi\epsilon_0}\left(q_A \ln \frac{GMD}{r} + q_C \ln \frac{r}{GMD}\right)$$

$U_{AB} + U_{AC}$

$$q_A + q_B + q_C = 0 \qquad -q_A = q_B + q_C$$

$$V_{AB} + V_{AC} = \frac{1}{2\pi\epsilon_0}\left[2q_A \ln \frac{GMD}{r} + q_A \ln \frac{GMD}{r}\right]$$

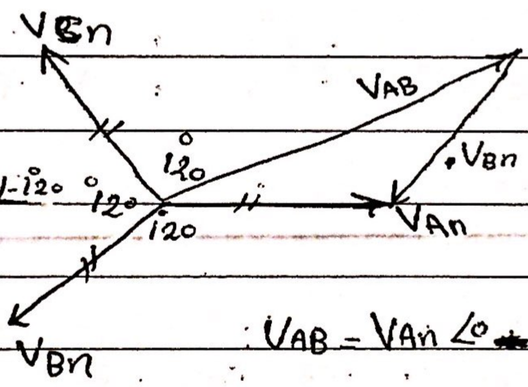
$$V_{AB} + V_{AC} = \frac{1}{2\pi\epsilon_0}\left(3q_A \ln \frac{GMD}{r}\right) \rightarrow *$$

$V_{AC} = V_{An}\angle 0^\circ - V_{An}\angle -240^\circ$

$U_{AB} + V_{AC} = 2V_{An}\angle 0^\circ - V_{An}\angle -120^\circ$

$- V_{An}\angle -240^\circ$

$= 3V_{An}$



$U_{AB} = V_{An}\angle 0^\circ - V_{An}\angle 120^\circ$

$U_{AB} = V_{An}\angle 0^\circ - V_{Bn}\angle 0^\circ$

for Balance (3-Ph) voltages :-

$$\cancel{3}V_{An} = \frac{\cancel{3}q_A}{2\pi\epsilon_0} \ln \frac{GMD}{r}$$

$$\boxed{C_{an} = \frac{q}{V} = \frac{2\pi\epsilon_0}{\ln \frac{GMD}{r}} \; f/m}$$

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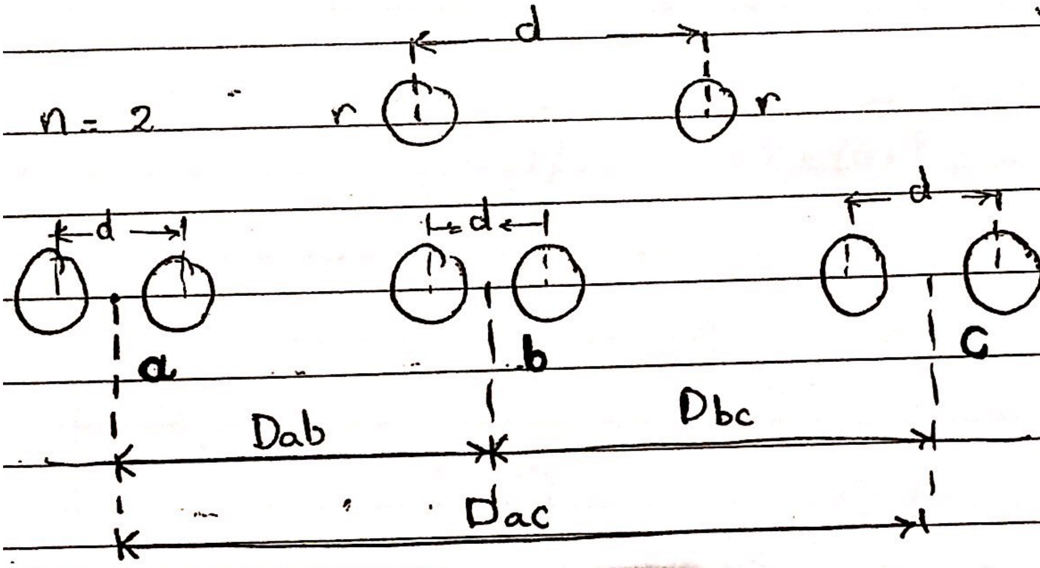
$$C = \frac{2\pi \epsilon_0}{\ln \frac{GMD}{r}} \quad (F/m)$$

$$C = \frac{0.055}{\ln \frac{GMD}{r}} \quad (\mu F/km)$$

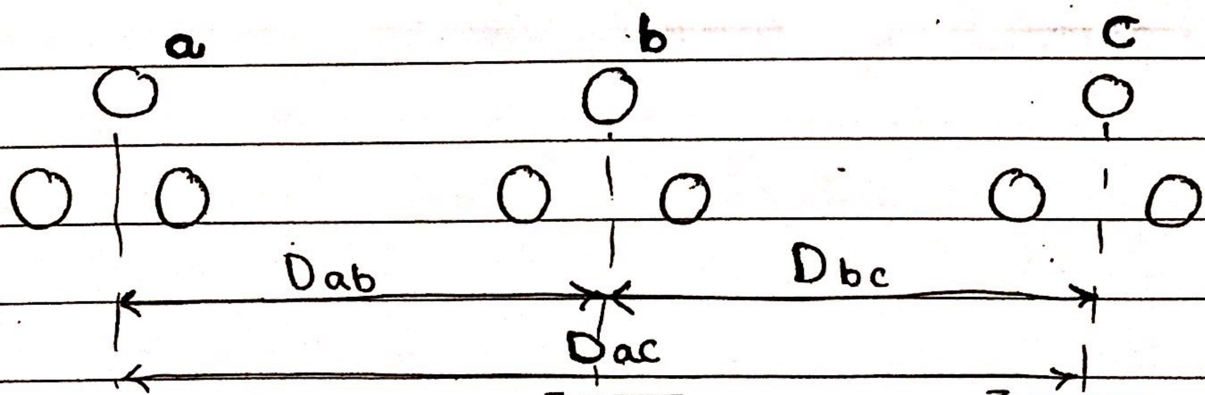
for bundle conductor :-



r(b) = bundle

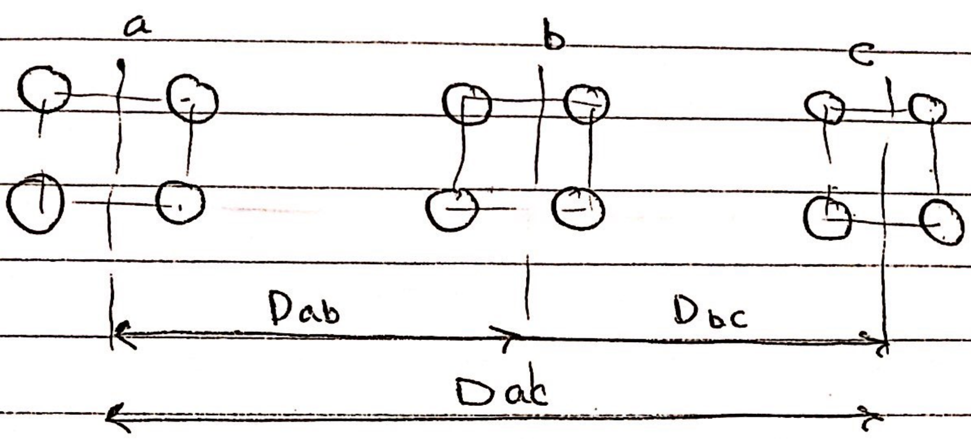
$$C = \frac{2\pi \epsilon_0}{\ln \frac{GMD}{r(b)}} \qquad r(b) = \sqrt{r\, d}$$

n = 3



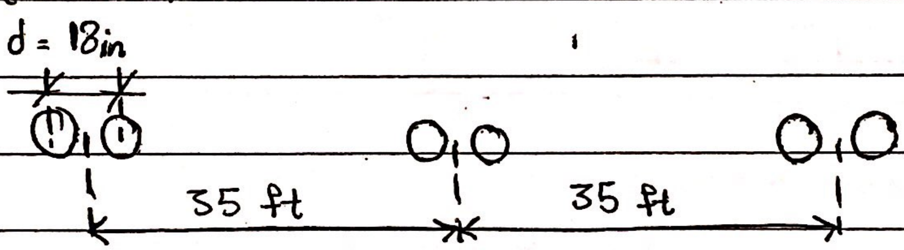
$$GMD = \sqrt[3]{} \qquad r(b) = \sqrt[3]{r\, d^2}$$

(8) $n = 4$



$$r_{(b)} = \sqrt[4]{r d^3} \cdot (1.09)$$

* Ex:- #1



diam = 0.977 inch.

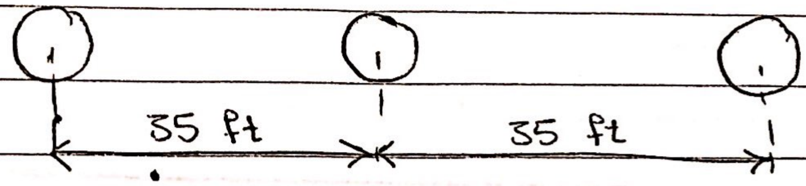
solution

$$GMD = \sqrt[3]{(35)(35)(70)} = 44.087 \text{ ft}$$

$$r_{(b)} = \frac{\sqrt{\left(\frac{0.977}{2}\right) \times 18}}{12} = 0.2471 \text{ ft.}$$

$$C = \frac{0.0556}{\ln \frac{44.087}{0.2471}} = 0.0107 \ \mu F/km.$$

* Ex :- # 2



Diam = 1.345 in

solution

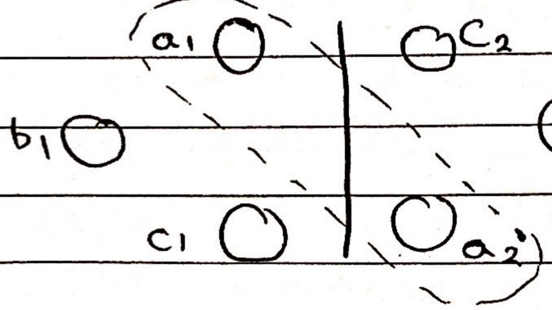
$$r = (1.345 \div 2)/12 = 0.056 \text{ ft}$$

$$C = \frac{0.0556}{\ln \frac{44.097}{0.056}} = 0.0083 \ \mu F/km$$

$$\% \text{ increase in } C = \frac{0.0107 - 0.0083}{0.0083} \times 100$$

$$\simeq 28.9\%$$

Capcitance for duble Circuit Line :-



$$C = \frac{2\pi \epsilon_o}{\ln \frac{GMD}{GMR_c}}$$

GMD :- Same as inductance,

for GMR_c ?

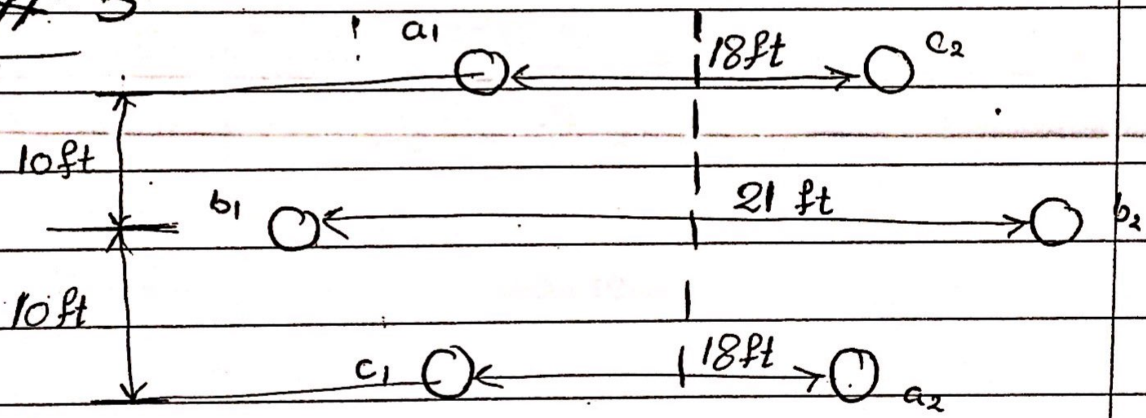
$$r_A = \sqrt{r\, D_{a_1a_2}}$$

$$r_B = \sqrt{r\, D_{b_1b_2}}$$

$$r_C = \sqrt{r\, D_{c_1c_2}}$$

$$GMR_c = \sqrt[3]{r_A\, r_B\, r_C}$$

Ex :- # 3



solution

Tables

Diam = 0.68 in

$$r = \frac{0.68}{2 \times 12} = 0.0283 \text{ ft}$$

GMD = 16.1 ft

$$D_{a_1a_2} = D_{c_1c_2} = \sqrt{18^2 + 20^2} = 26.9 \text{ ft}$$

$$D_{b_1b_2} = 21 \text{ ft}$$

$rA = rc = \sqrt{0.0283 \times 26.9} = 0.873\ ft$

$rb = \sqrt{0.0283 \times 21} = 0.7709\ ft$

$GMR_c = \sqrt[3]{(0.873)^2 \times 0.7709} = 0.837\ ft$

$$C = \frac{0.0556}{\ln \frac{16.1}{0.837}} = 18.807 \times 10^{-12}\ f/m = 0.018807\ \mu f/km$$

* Capacitive susceptance?

$$B_c = \frac{1}{X_c}$$

$$B_c = 2\pi f C$$

$$= 2\pi (60)(18.807 \times 10^{-12})\ \frac{S}{\cancel{m}} \cdot \frac{1609\ \cancel{m}}{mil}$$

$$= 11.41 \times 10^{-6}\ S/mil/phase$$

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Use of tables :-

$$X_L = 2\pi f L$$

$$X_L = 2\pi f \left(2\times10^{-7} \ln \frac{GMD}{GMR}\right)$$

$$= 4\pi f \times 10^{-7} \ln \frac{D_{m \to \text{mutual}}}{D_{s \to \text{selve}}} \quad (\Omega/m)$$

$$= 4\pi f \times 10^{-7} \ln \frac{D_m}{D_s} \times \frac{\Omega}{m} \cdot \frac{1609 m}{mil}$$

$$= 2.022\times10^{-3} f \ln \frac{D_m}{D_s} \quad (\Omega/mil)$$

$$= 2.022\times10^{-3} f \ln \frac{1}{D_s} +$$

$$2.022\times10^{-3} f \ln D_m \quad (\Omega/mil)$$

1. inductive Reactance at 1-ft spaceing :-

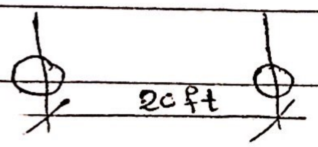
$$X_a = 2.022\times10^{-3} f \ln \frac{1}{D_s}$$

2. inductive Reactance at spaceing factor :-

$$X_d = 2.022\times10^{-3} f \ln D_m$$

NOTE BOOK

* Ex :- # 4 Partridge



single-ph line :-

find the inductive Reactance / mil ?

solution

GMR = D_s = 0.0217 ft

$$X_L = 2\pi(60) \times 2\times10^{-7} \cdot \ln \frac{20}{0.0217} \times 1609 = 0.828 \ \Omega/\text{mile}$$

Using Table

$X_a = 0.465 \ \Omega/\text{mil}$

$X_d = 0.3635 \ \Omega/\text{mil}$

$X_L = X_a + X_d$

$= 0.465 + 0.3635 = 0.8285 \ \Omega/\text{mile}$

$X_{line} = 2 \times 0.8285 = 1.656 \ \Omega/\text{mil}$

$X_d = 0.2794 \log d$

$$X_C = \frac{1}{WC} = \frac{1}{2\pi f C} = \frac{1}{2\pi f} \frac{\ln(D/r)}{(2\pi \epsilon_0)}$$

$$X_C = \frac{2.862 \times 10^9}{f} \ln\left(\frac{D}{r}\right) \quad \Omega\text{-m}$$

$$X_C = \frac{2.862 \times 10^9}{f} \ln\left(\frac{D}{r}\right) \times \frac{1 \text{ mil}}{1609 \text{ m}}$$

$$X_C = \frac{1.779 \times 10^6}{f} \ln\left(\frac{D}{r}\right) \quad (\Omega\text{-mil to nutral})$$

$$X_C = \frac{1.779}{f} \times 10^6 \ln\frac{1}{r} + \frac{1.779}{f} \times 10^6 \ln D$$

Capacitave Reactance to nutral at 1-ft spacing :-

$$X_a' = \frac{1.779}{f} \times 10^6 \ln\frac{1}{r}$$

Capacitave Reactance spacing factor :-

$$X_d' = \frac{1.779}{f} \times 10^6 \ln D$$

* Ex :- 5 # :-

$X_a' = 0.1074 \text{ M}\Omega\text{-mil}$

$X_d' = 0.0889 \text{ M}\Omega\text{-mil}$

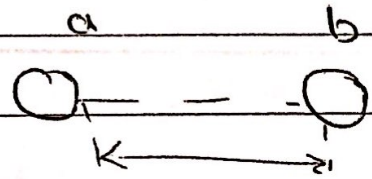
$X_C = X_a' + X_d' = 0.1963 \text{ M-}\Omega \text{ mil/cond}$

$X_{C_{Lin\ to\ Lin}} = 2 \times 0.1963 \times 10^6 = 0.392 \text{ M}\Omega\text{-mil}$

$B_C = \frac{1}{X_C} = 2.55 \times 10^{-6} \text{ S/mil}$

* to Calculate Charging Current :-

ⓐ single - Phase Lines :-



$$I_{charge} = B_{L-L} \cdot V_{L-L}$$
$$= j w C_{a-b} \cdot V_{a-b}$$

ⓑ 3-Ph Line :-

$$I_{charge} = V_{Ph} \cdot B_{to\ neutral}$$
$$= j w C_n \cdot V_{an}$$

Quiz #1 :- Solution :-

AAC (61) strand , 1113000 CMil

$R_{dc}(20^\circ) = 0.01552\times10^{-3}\ \Omega/ft$

$R_{ac}(60Hz, 50C^\circ) = 0.0951\ \Omega/mil$

1.6% spiraling

(a) $R_{20} = \rho_{20}\frac{L}{A}$

$= 17\ \frac{\Omega\text{-}Cmil}{ft} \times \frac{1\ ft}{1113000\ Cmil} \times 1.016 = \boxed{\ }\ \Omega\ 0.015518\times10^{-3}\ \Omega/ft$

$= 1.552\times10^{-5}\ \Omega/ft$

(b) $\frac{R_{ac}}{R_{DC}} =$

$R_{dc}(50c^\circ) = R_{dc(20)}\ \frac{50 + T}{20 + T} = \boxed{\ }\ \frac{\Omega}{ft} \times \frac{5280\ ft}{mil}$

$R_{dc}(50c^\circ) = 0.01552\times10^{-3}\left(\frac{228.1+50}{228.1+20}\right)\times 5280$

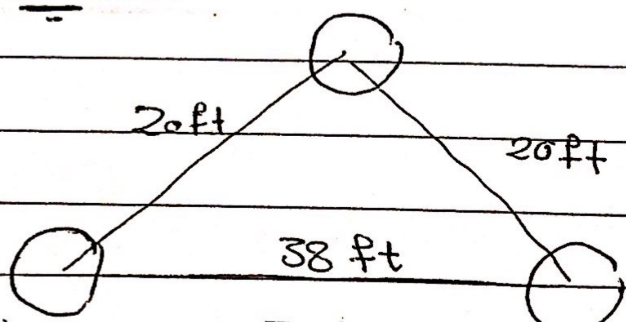
$= 0.0918\ \Omega/mil$

% increase in $(R) = \frac{0.0951 - 0.0918}{0.0918} \times 100 = 3.5\%$

* Ex :- # 1 :-

(Drake)

ACSR



3Ph - Line

find the Cap (c),

Cap Reactance (X_c), f = 60Hz

Line Length is 175 mil and at (220kV)

find the total Cap. Reactance to nutral and Charge Current.

$$C = \frac{2\pi \epsilon_0}{\ln \frac{D_{eq}}{r}} \quad (F/m)$$

لما تزيد المسافة
Xc تقل

shunt
عكسي مع
الطول
كل ما زاد الطول ينقص
shunt

$$D_{equ} = \sqrt[3]{20 \times 20 \times 38} = 24.8 \text{ ft}$$

$$r = \frac{1.108}{2 \times 12} = 0.0462 \text{ ft}$$

$$C = \frac{2\pi * 8.8 \times 10^{-12}}{\ln \frac{24.8}{0.0462}} = 8.8 \times 10^{-12} \text{ F/m}$$

$$x_C = \frac{1}{WC} = \frac{1}{2\pi(60) \times 8.8 \times 10^{-12} \text{ F/m}} = \boxed{} \ \Omega\text{-m} = \frac{\boxed{}\ \Omega\text{-m}}{1609 \text{ m/mil}}$$

$$= 0.1865 \times 10^{6} \ \Omega\text{-mil to nutral} = 0.1865 \text{ M-mil-}\Omega$$

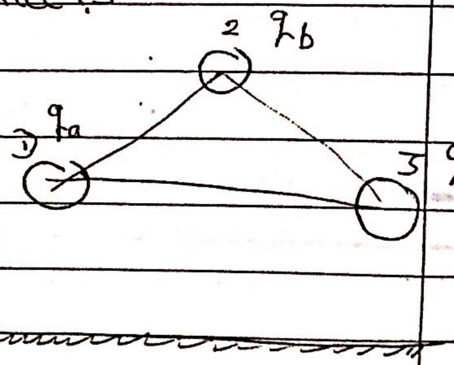
$$(x_C) \text{ for the line} = \frac{0.1865 \text{ M } \Omega\text{-mil}}{175 \text{ mil}} = 1066 \ \Omega\text{-to nutral}$$

$$I_{ch} = W C_n V_{ph} = 2\pi(60)(8.8 \times 10^{-12} \text{ F/m} * \frac{1609 \text{ m}}{\text{mile}}) \times 175 \text{ mil} * \left(\frac{220 \times 10^{3}}{\sqrt{3}}\right) = 119 \text{ A} = 0.68 \text{ A/mil}$$

$$I_{ch} = \frac{(220 \times 10^{3}/\sqrt{3}) \text{ v}}{1066 \ \Omega} = \frac{V}{x_C}$$

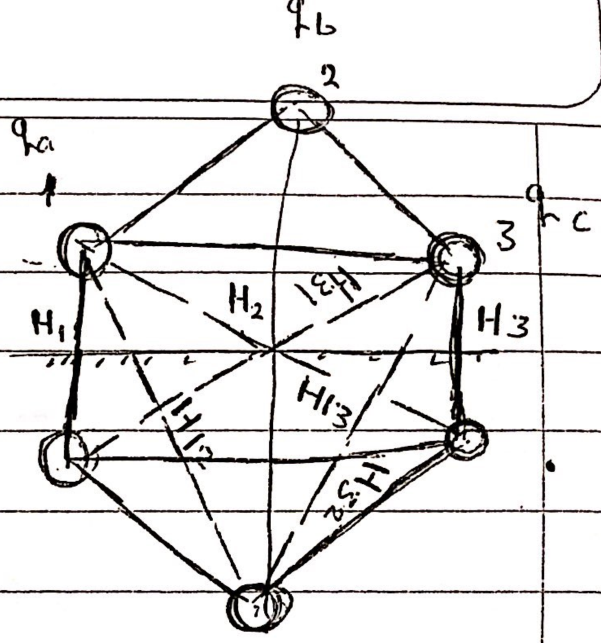
$$I_{ch} = \boxed{}$$

* effect of Earth on the Capacitance :-



$$C_n = \frac{2\pi\epsilon_0}{\ln\frac{D}{r} - \ln\left(\sqrt[3]{H_{12}H_{13}H_{23}} \Big/ \sqrt[3]{H_1 H_2 H_3}\right)}$$

3-Ph
Voltage Lin-Lin
$\sqrt{3} * V$



2015/4/9

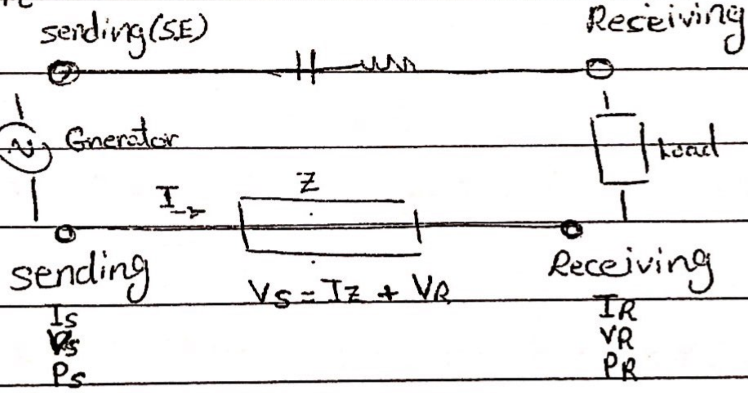
Transmission line model :-

* Line performance under normal operting Conditions :-

(V_{LN} , I) → (Per Phase)

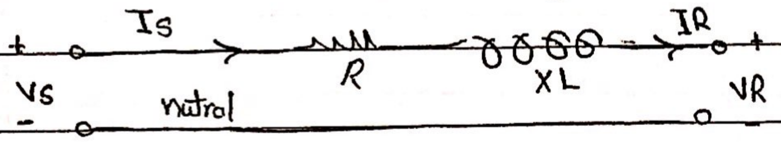
$V_{LN} = \sqrt{3}\ V_{ph}$

* (R, L, C)
* (R, XL, Xc)



① short line $L \leq 80\ km = 50\ mil$

(C) is neglected



$Z = R + jXL$

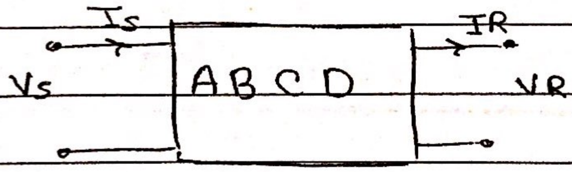
$V_s = V_R + I_R Z$ → ① $\boxed{I_s = I_R}$

$I_s = I_R$ → ②

$Z = (r + j\omega L) * l$ ← (length)

$r = \Omega/km$ $L = H/km$

Z = total line impedance (Ω)



$V_s = A\ V_R + B\ I_R$ → ①'

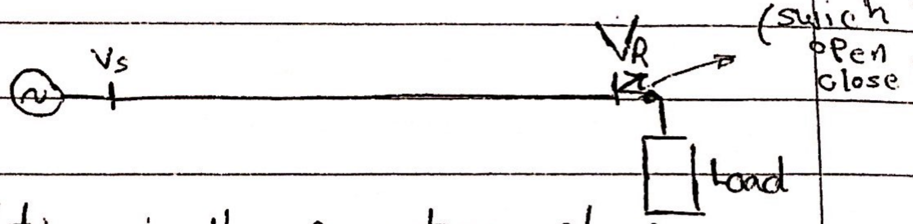
$I_s = C\ V_R + D\ I_R$ → ②'

from ① ①' and ② ②'

$A = 1$
$B = Z$
$C = 0$
$D = 1 = A$

Voltage regulation (VR) :-

الفرق في الجهد في حالة وجود Load وعدم وجود Load في Receiving

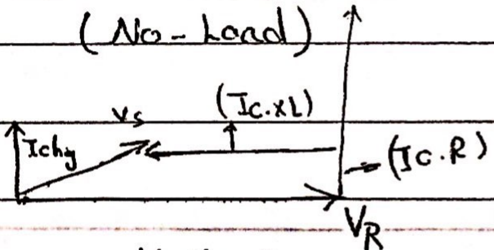


The Voltage Regulation is the percentage change in Voltage at the (R.E) in the line (expressed as percent of F.L Voltage) in going from Load to full Load.

$$\% VR = \frac{|V_{R\,(\text{no-Load})}| - |V_{R\,(\text{Full-Load})}|}{|V_{R\,(\text{full-Load})}|} \times 100 = \%$$

Ferranti - effect
هي ظاهرة الجهد في نهاية الخط في حالة No Load

(No - Load)



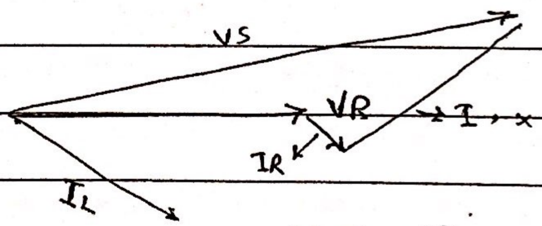
$V_s < V_R$
(Lead p.f)

L → (I → يتأخر (90) → V)

C → (I → يتقدم (90) → V)

R → (I = V ∠0°)

(Load)



$V_s > V_R$
(Lag P.f)

2015 /4 /13

* efficiency of Line $(\eta) = \frac{P_R(3\phi)}{P_s(3\phi)}$ S 90MW R 80MW

$$\eta = \frac{80}{90}$$

* Ex:- # 1

A 220kv, 3-Ph, 60HZ Transmission Line is 40km Long.

$r = 0.15\ \Omega/Ph/Km$

$L = 1.3263\ mH/ph/Km$

C = neglected

The Load at (R.E) is (381 MVA) at (0.8 P.F) Lag and 220kv. Using short Line model find the voltage And power at the (S.E) and (VR) and (η)

solution

$S = 381$ MVA I_R

$$I_R = \frac{381 \times 10^3\ KVA}{\sqrt{3}\ 220\ KV} \angle \cos^{-1} 0.8 = 1000 \angle -36.87^\circ\ A$$

note :-

$S\ V_P\ 3\phi$

$3.\phi\ \frac{}{\sqrt{3}}\ V_{ph}$

~~single phase~~

$S\ 3\phi$

$3 . \frac{V_L}{\sqrt{3}}$

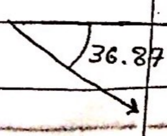
V_s R.E

$$Z = \left[0.15 + j(2\pi * 60 * 1.3263 \times 10^{-3})\right] * 40\ km$$

$$Z = 6 + j\,20\ \Omega$$

$$V_s = V_R + I_R . Z$$

$$= \frac{220}{\sqrt{3}} \angle 0^\circ + \left[(1000 \angle -36.87^\circ) + j(6 + j20)\right] \times 10^{-3}$$



$V_s = 144.33 \angle 4.93^\circ$ KV (phase)

AL:daerey...

$V_{s(L-L)} = \sqrt{3} \times 144.33$

$= 250 \text{ kV}$

$S_s = V_s I_s^*$

$S_{s(3ph)} = 3(144.33\angle 4.93^\circ)(1000\angle +36.87)$

$= 432990 \angle 41.80^\circ$

$P_s = 432.99 \cos 41.8^\circ = 322.78 \text{ MW}$

$P_R = 304.8 \text{ MW}$

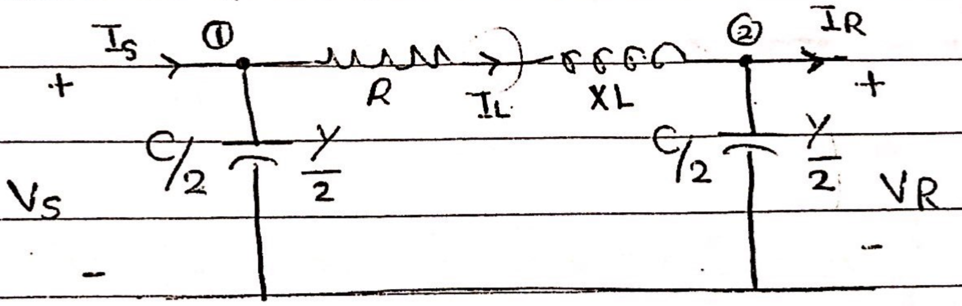
$$\eta = \frac{P_R}{P_S} \times 100 = \frac{304.8}{322.78} \times 100 = 94\%$$

$$\text{Voltage Regulation} = \frac{|V_S| - |V_R|}{|V_R|} \times 100$$

$$= \frac{250-220}{220} \times 100 = 13.6\%$$

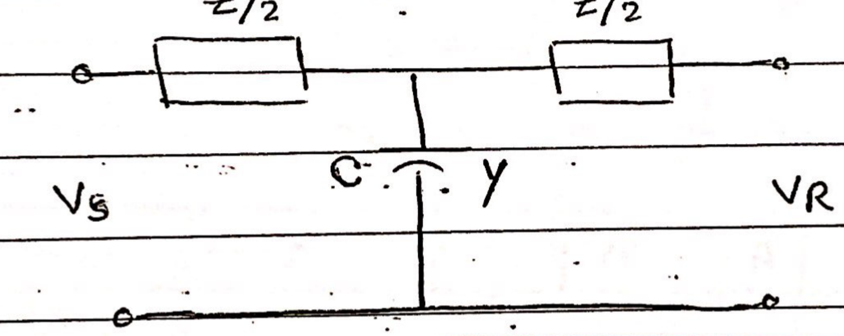
* meduim- length Line model :-

$80\,km < L < 250\,km$



nominal -π model

The line is meduimlength and chargin current increases → the capacitance must be taken into account



$Y = G + j\omega C$

$G =$ مهملة

$Y = j\omega C \qquad Y/2 = \omega C/2$

at node② KCL :-

$I_1 = I_R + \frac{Y}{2} \cdot V_R \longrightarrow ①$

KVL :-

$V_S = V_R + I_1 Z \longrightarrow ②$

$V_S = V_R + Z\left[I_R + \frac{Y}{2} V_R\right]$

$V_S = V_R + Z I_R + \frac{ZY}{2} V_R$

$V_S = V_R\left(1 + \frac{ZY}{2}\right) + Z I_R$

$V_S = A\, V_R + B\, I_R$

$A = 1 + \frac{ZY}{2}$
$B = Z$
$C = Y\left(1 + \frac{ZY}{4}\right)$
$D = A = \left(1 + \frac{ZY}{2}\right)$

node ① KCL :-

$$I_S = I_L + V_S \frac{Y}{2}$$

$$I_S = I_R + \frac{Y}{2} V_R + \frac{Y}{2}\left[\left(1 + \frac{ZY}{2}\right)V_R + Z I_R\right]$$

$$I_S = I_R + \frac{Y}{2} V_R + \frac{Y}{2} V_R + \frac{Y}{2}\frac{ZY}{2} V_R + \frac{YZ}{2} I_R$$

$$I_S = Y\left(1 + \frac{ZY}{4}\right)V_R + \left(1 + \frac{ZY}{2}\right)I_R$$

$$I_S = C\,V_R + D\,I_R$$

$$\begin{vmatrix} A & B \\ C & D \end{vmatrix} = 1$$

$$AB - BC = 1$$

$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{pmatrix} A & B \\ C & D \end{pmatrix}\begin{pmatrix} V_R \\ I_R \end{pmatrix} \Longrightarrow \begin{pmatrix} V_R \\ I_R \end{pmatrix} = \begin{pmatrix} A & B \\ C & D \end{pmatrix}^{-1}\begin{pmatrix} V_S \\ I_S \end{pmatrix}$$

$$V_R = D\,V_S - B\,I_S$$

$$I_R = -C\,V_S + A \cdot I_S$$

* Ex :- #2 A $\overset{\text{Design Voltage}}{\overline{345}}$-kV, 3-Ph transmission line is 130km long.

$r = 0.036\ \Omega/Ph/km$

$L = 0.8\ mH/Ph/km$

$C = 0.0112\ \mu F/km$

H.w#1

the load at the R.E is 270 MVA at 0.8 p.F lag at 325 kv . using medium modlel find V_s , P_s , V_R ?

Line (3-Ph)

V_s R.E

- 270 MVA
- 0.8 lag
- 325 kv

$$V_R = \frac{325}{\sqrt{3}} \angle 0^\circ$$

$$I_R = I_L = \frac{270 \times 10^3 \text{ kVA}}{\sqrt{3} \times 325} \angle -36.87^\circ = 479.64 \angle -36.87^\circ$$

$$A = 1 + \frac{ZY}{2} \quad , \qquad Z = \left(0.636 + j\left(2\pi * 60 \times 0.8 \times 10^{-3}\right)\right) * 130$$

$$A = D \qquad Y = j\omega C = j\left(2\pi \times 60 \times 0.0112 * 10^{-6}\right) \times 130$$

$$C = Y\left(1 + \frac{ZY}{4}\right)$$

$$D = A$$

$$VR = \frac{|V_{R\,No.Load}| - |V_{R\,Full\text{-}Load}|}{|V_{R\,Full\text{-}Load}|}$$

$$= \frac{(V_s/A) - V_R}{V_R}$$

$V_s = 199.187 \angle 4.012$ kv/ph

$I_s = 421.127 \angle -25.56$ A

$S_s = 251.64$ MVA $\angle 29.572$

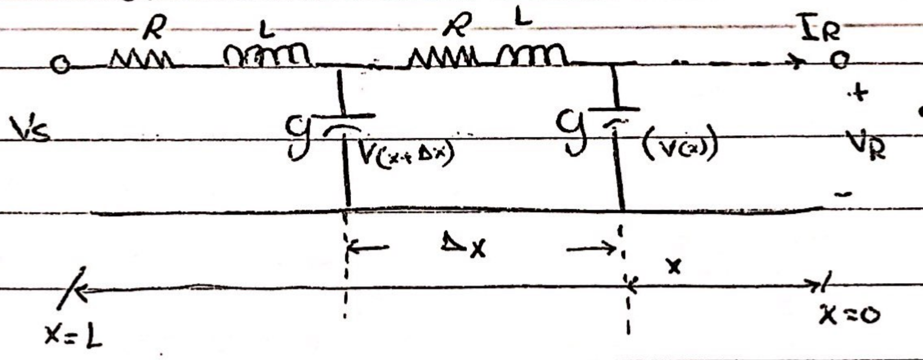
$P_s = 218.868$ MW

$P_R = 215.99$ MW

2015/4/16

* Long-Line model :- $L > 250$ km

the parameters (r, L, c) are uniformly distributed.



$Z = r + j\omega L$ / unit Length $= Z\,\Delta x$

$y = \cancel{G} + j\omega c$ / unit length $= y\,\Delta x$

for small segment of the Line (Δx) at a distance (x) from (R.E)

* KVL :-

$$V(x+\Delta x) = V(x) + Z\,\Delta x\, I(x)$$

$$\frac{V(x+\Delta x) - V(x)}{\Delta x} = Z\, I(x) \longrightarrow (1)$$

take Limit as $\Delta x \to 0$

$$\frac{dV(x)}{dx} = Z\, I(x) \longrightarrow (2)$$

* KCL :-

$$I(x+\Delta x) = I(x) + y\,\Delta x\, V(x+\Delta x)$$

$$\frac{I(x+\Delta x) - I(x)}{\Delta x} = y\, V(x+\Delta x)$$

take limit as $\Delta x \to \infty$

$$\frac{dI(x)}{dx} = y\, V(x) \longrightarrow (3)$$

diff (2) $\Rightarrow$ $$\frac{d^2V(x)}{dx^2} = Z \cdot \frac{dI(x)}{dx} \longrightarrow (4)$$

$$\frac{d^2V(x)}{dx^2} = Zy\, V(x) \Rightarrow Zy = \gamma^2$$

$$\boxed{\frac{d^2V(x)}{dx^2} = \gamma^2\, V(x)}$$

solving this (2^{nd}) order diff equ :

$$V(x) = A_1 e^{\gamma x} + A_2 e^{-\gamma x} \longrightarrow (5)$$

$\gamma = \sqrt{yZ}$: is know as the propagation Constant , a Complex

$\gamma = \alpha + j\beta$

α = Attenuation Constant nepar/(Km)or(mil)

β = Phase Constant $\frac{\text{rad}}{(\text{Km})\text{or}(\text{mil})}$

(1) $\rightarrow$ $$I(x) = \frac{1}{Z}\frac{dV(x)}{dx}$$

$$= \frac{\gamma}{Z}\left[A_1 e^{\gamma x} - A_2 e^{-\gamma x}\right]$$

$$= \sqrt{\frac{y}{Z}}\left[A_1 e^{\gamma x} - A_2 e^{-\gamma x}\right]$$

$$= \frac{1}{\sqrt{Z/y}}\left(A_1 e^{\gamma x} - A_2 e^{-\gamma x}\right)$$

Let $Z_c = \sqrt{Z/y}$ = characteristic impedance.

$$I(x) = \frac{1}{Z_C}\left(A_1 e^{\gamma x} - A_2 e^{-\gamma x}\right)$$

$x = L$ $x = 0$

V_S V_R

at $(x=0)$, $V(0) = V_R$

$$V_R = A_1 + A_2$$

$$I_R = \frac{A_1 - A_2}{Z_C}$$

$$A_1 = (V_R + Z_C I_R)/2 \quad , \quad A_2 = (V_R - Z_C I_R)/2$$

$$V(x) = \frac{V_R + Z_C I_R}{2} e^{\gamma x} + \frac{V_R - Z_C I_R}{2} e^{-\gamma x}$$

$$I(x) = \frac{(V_R/Z_C) + I_R}{2} e^{\gamma x} - \frac{(V_R/Z_C) - I_R}{2} e^{-\gamma x}$$

* re-arranging.

$$V(x) = \frac{e^{\gamma x} + e^{-\gamma x}}{2} V_R + Z_C \frac{e^{\gamma x} - e^{-\gamma x}}{2} I_R$$

$$V(x) = \cosh(\gamma x)\, V_R + Z_C \sinh(\gamma x)\, I_R$$
$$= A \; V_R + B \; I_R$$

$$\boxed{\begin{aligned} A &= \cosh(\gamma x) \\ B &= Z_C \sinh(\gamma x) \end{aligned}}$$

$$I(x) = \frac{1}{Z_c} \frac{e^{\gamma x} - e^{-\gamma x}}{2} V_R + \frac{e^{\gamma x} + e^{-\gamma x}}{2} I_R$$

$$= \frac{1}{Z_c} \sinh(\gamma x) V_R + \cosh(\gamma x) I_R$$

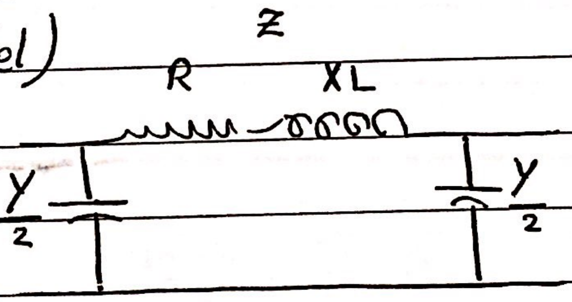
$$\boxed{\begin{aligned} C &= {}^{1}/_{Z_c} \sinh(\gamma x) \\ D = A &= \cosh(\gamma x) \end{aligned}}$$

$V(L) = V_{Send}$
$I(L) = I_{Send}$

$$\begin{pmatrix} V_{s(x)} \\ I_{s(x)} \end{pmatrix} = \begin{pmatrix} A & B \\ C & D \end{pmatrix} \begin{pmatrix} V_R \\ I_R \end{pmatrix}$$

$V(0) = V_{Rece}$
$I(0) = I_R$

Equivalent - (π model)



nominal (π)

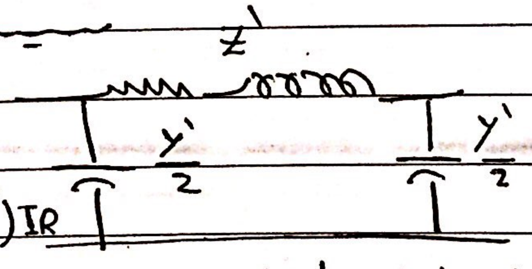
$$V_s = \left(1 + \frac{ZY}{2}\right) V_R + Z I_R$$

$$I_s = \left(1 + \frac{ZY}{4}\right) Y V_R + \left(1 + \frac{ZY}{2}\right) I_R$$

①

$$V_s = \left(1 + \frac{Z'Y'}{2}\right) V_R + Z' I_R$$

$$I_s = \left(1 + \frac{Z'Y'}{4}\right) Y' V_R + \left(1 + \frac{Z'Y'}{2}\right) I_R$$



Equivalen (π model)

28/3/2017

AL-daeref

(2) $V_S = \cosh(\gamma L)\, V_R + Z_c \sinh(\gamma L)\, I_R$

$I_S = \frac{1}{Z_c} \sinh(\gamma L)\, V_R + \cosh(\gamma L)\, I_R$

Comparing (1) , (2)

$$Z' = Z_c \sinh(\gamma L) = Z \frac{\sinh(\gamma L)}{\gamma L}$$

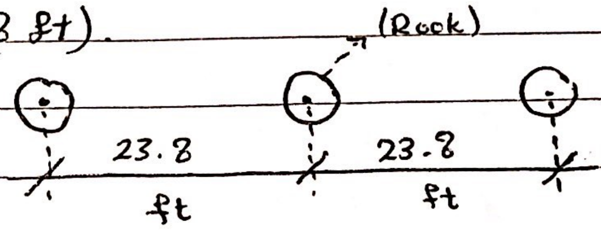
$$\frac{Y'}{2} = \frac{1}{Z_c} \tanh\left(\frac{\gamma L}{2}\right) = \frac{Y}{2} \frac{\tanh(\gamma L/2)}{(\gamma L/2)}$$

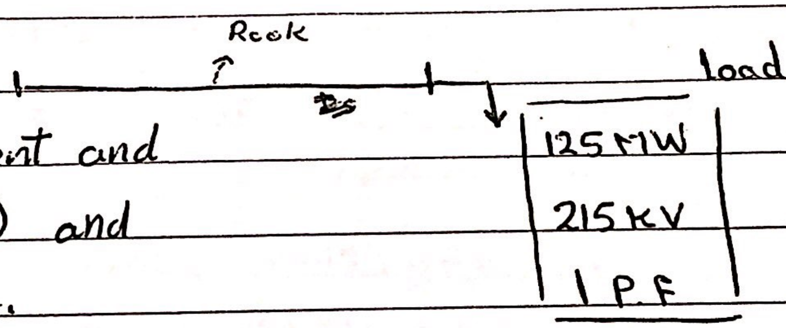
(H.W #2) 2015 / 4 / 20

* Ex :- ~~# 1~~ long Line

A single-Circuit, (60 Hz), (3-ph) transmission Line is (230 mil) Long, The Conductors are (Rook) with a flat horizontal spacing of (23.8 ft).

the load on the Line is (125 MW) at (215 kV), Unity (P.f).





find the Voltage, Current and Power at the (S.E) and voltage Regulation.

solution

$V_S = A V_R + B I_R$

$A = \cosh(\gamma L)$

$B = Z_C \sinh(\gamma L)$

$V_R = \frac{215}{\sqrt{3}} \angle 0^\circ \ V$, $I_R = \frac{125 \times 10^3}{\sqrt{3} \times 215 \times 1} \angle 0^\circ \ A$

$\gamma = \sqrt{Z\,y}$

$Z = r + jX_L$ use Table at (50 c°) Rook

$r = 0.1603 \ \Omega/m$

$X_L = X_a + X_d$

for $X_a = 0.415 \ \Omega/mil$

for $X_d \Longrightarrow GMD = \sqrt[3]{(23.8)(23.8)(47.6)}$

$= 30 \ ft$

$X_d = 0.4127 \ \Omega/mil$

$X_L = X_a + X_d = 0.8277 \ \Omega/mil$

※ $Z = 0.1603 + j0.8277 \ \Omega/mil$

$y = j\omega c = j \frac{1}{xc}$

use Table

$xc = xa' + xd'$

for $xa' = 0.095 \ M\Omega - mil$

for $xd' = 0.1009 \ M\Omega - mil$

$xc = 0.1959 \times 10^6 \ \Omega \ mil$

※ $y = j \frac{1 \times 10^{-6}}{0.1959} \ s/mi = 5.105 \times 10^{-6} \angle 90 \ s/mil$

$Z = 0.8431 \angle 79.04^\circ \ \Omega/mil$

$y = 5.105 \times 10^{-6} \angle 90 \ s/mil$

$\gamma = \alpha + j\beta = \sqrt{Zy} = \sqrt{(0.8431) * (5.105 \times 10^{-6})} \angle \frac{90 + 78.04^\circ}{2}$

$\gamma L = 230 \times \sqrt{Zy} = 0.4772 \angle 84.52^\circ$

$A = \cosh \gamma L = \cosh(\alpha L) . \cos(\beta L) + j \sinh(\alpha L) . \sin(\beta L)$.

$B = jZc \sinh(\gamma L)$

$Zc = \sqrt{Z/y} = \sqrt{\frac{0.8431}{5.105 \times 10^{-6}}} \angle \frac{78.04 - 90}{2} \rightarrow$ Range $(0 \rightarrow -15^\circ)$

$Zc = 406.4 \angle -5.48^\circ \ \Omega$

$V_{Lin} = \sqrt{3} \ V_{Ph}$

$Vs = A V_R + B I_R = V_{S(ph)}$

$Is = C V_R + D I_R$

$C = j \frac{1}{Zc} \sinh(\gamma L)$

$D = A$

θ الفرق بين

$P_S = 3 V_{s(ph)} \cdot I_s \cos \theta_s$

$S_{S(3\phi)} = 3 \overline{V_{s(ph)}} \ I^*_{s0} = | | \angle \theta$

$$\text{Voltag Regulation} = \frac{|V_s/A| - |V_R|}{|V_R|} \times 100 =$$

* Lossless Line :-

$$\gamma = \alpha + jB = \sqrt{(\cancel{r} + j\omega L)(\cancel{G} + j\omega C)}$$
$$= j\omega\sqrt{LC}$$

$\alpha = 0$ no Attenuation

$jB = j\omega\sqrt{LC}$ $\quad \beta = \omega\sqrt{LC}$

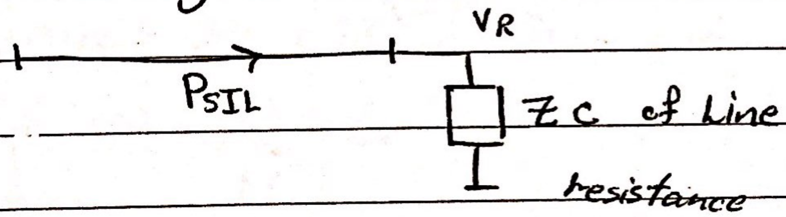
$$Z_C = \sqrt{\frac{Z}{y}} = \sqrt{\frac{r + j\omega L}{G + j\omega C}}$$

$$Z_C = \sqrt{\frac{L}{C}} \equiv \text{Surge impedance}$$

* SIL :-

surge impedance loading

$$Z = \frac{|V|^2}{S^*}$$



$$I_R = \frac{V_R}{\sqrt{\frac{L}{C}}} = \frac{V_R}{Z_C}$$

$$P = 3V_{ps}\, I$$

$$P = \cancel{3}\,\frac{V_L}{\sqrt{3}} * \frac{V_L}{\sqrt{3}} * \frac{1}{\sqrt{L/C}}$$

$$P = \frac{|V_L|^2}{Z_C} \quad (MW)$$

* STL :- Surage impedance Loading of a Line is the power delivered by the Line to a purely

Resistive Load equal to it's surge impedance.

* Wave length (λ) :-
is the distance along a Line between two points of a wave which diff 2π or $360°$

$$\lambda = \frac{2\pi}{\beta} \text{ (km) or (mil)}$$

* Velocity of propagation of wave :- (km/s) (mil/s)

$$V = \lambda \text{ (km)} * f \text{ (HZ)}$$

$$V = \frac{2\pi}{\beta} * f$$

$\lambda = 5000 \text{ km}$

$V = 3 \times 10^8 \text{ m/s}$ #

$$V = \frac{1}{\sqrt{LC}}$$

$$V_S = \cosh(\gamma L)\, V_R + \sinh(\gamma L)\, Z_C\, I_R$$

$$\cosh(\gamma L) = \underbrace{\cosh(\alpha L)}_{1} . \cos(\beta L) + j\, \underbrace{\sinh(\alpha L)}_{\text{Zero}}\, \sin(\beta L)$$

$$\cosh(\gamma L) = \cos(\beta L)$$

$$\sinh(\gamma L) = j \sin(\beta L)$$

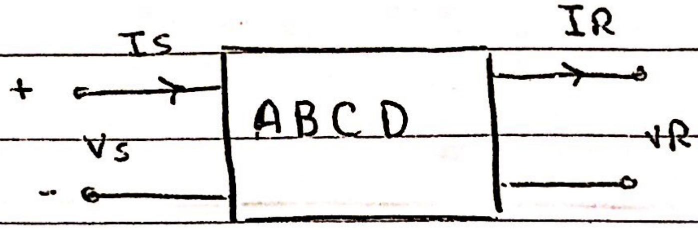
$$V_S = \cos(\beta L)\, V_R + j\, Z_C \sin(\beta L)\, I_R$$

$$I_S = j \frac{1}{Z_C} \sin(\beta L)\, V_R + \cos(\beta L)\, I_R$$

for Loss Less

2015/4/30

* Complex power flow trougth a transmission Line :-



$$V_S = A\,V_R + B\,I_R$$

$$I_S = C\,V_R + D\,I_R$$

(Power Angle) $\therefore S_{R(3\phi)} = P_{R(3\phi)} + j\,Q_{P(3\phi)}$ (Recever 3ϕ)

let $\bar{V}_S = |V_S| \angle \delta$, $\bar{V}_R = |V_R| \angle 0^\circ$

$\therefore \bar{A} = |A| \angle \theta_A^\circ$, $\bar{B} = |B| \angle \theta_B^\circ$

إنتقال Power ضروري ما يكون في زاوية بين (R) , (S)

$$I_R = \frac{V_S - A\,V_R}{B} = \frac{|V_S|\angle\delta - |A|\angle\theta_A\,|V_R|\angle 0^\circ}{|B|\angle\theta_B}$$

$$= \left|\frac{V_S}{B}\right| \angle \delta - \theta_B - \frac{|A||V_R|}{|B|} \angle \theta_A - \theta_B$$

$$S_{R(3\phi)} = 3\left(V_{R(Ph)} \cdot I_R^*\right)$$

Per Phase ضربت في 3 باش تغطي 3ϕ phase

$$S_{R(3\phi)} = 3\,|V_R| \angle 0^\circ \left[\frac{|V_S|}{B} \angle \theta_B - \delta - \frac{|A||V_R|}{|B|} \angle (\theta_B - \theta_A)\right]$$

$$S_{R(3\phi)} = 3\left|\frac{V_S V_R}{B}\right| \angle \theta_B - \delta - 3\left|\frac{A\,V_R^2}{B}\right| \angle \theta_B - \theta_A$$

* if (V_S) & (V_R) are Line Voltages :-

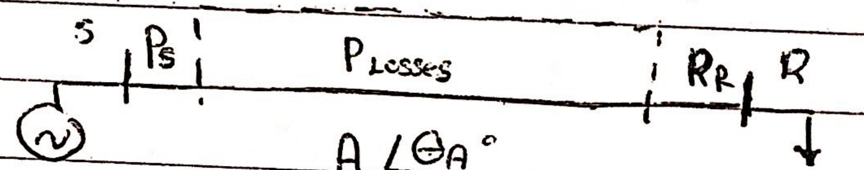
$$= \frac{3\,\frac{V_{S(L)}}{\sqrt{3}}\,\frac{V_{R(L)}}{\sqrt{3}}}{B} \angle \theta_B - \delta - \frac{3A\left(\frac{V_{R(L)}}{\sqrt{3}}\right)^2}{B} \angle \theta_B - \theta_A$$

NOTE BOOK

$$S_{R(3\phi)} = \left|\frac{V_{S(L)}\,V_{R(L)}}{B}\right| \angle \theta_B^\circ - \delta^\circ - \left|\frac{A\,V_{R(L)}^2}{B}\right| \angle \theta_B^\circ - \theta_A^\circ$$

$$P_{R(3\phi)} = \left|\frac{V_{S(L)}\,V_{R(L)}}{B}\right| \cos(\theta_B^\circ - \delta^\circ) - \left|\frac{A\,V_{R(L)}^2}{B}\right| \cos(\theta_B^\circ - \theta_A^\circ)$$

$$Q_{R(3\phi)} = \left|\frac{V_{S(L)}\,V_{R(L)}}{B}\right| \sin(\theta_B^\circ - \delta^\circ) - \left|\frac{A\,V_{R(L)}^2}{B}\right| \sin(\theta_B^\circ - \theta_A^\circ)$$



$A \angle \theta_A^\circ$

$B \angle \theta_B^\circ$

$V_S \angle \delta^\circ$

$V_R \angle 0^\circ$

P_R

Q_R

$$S_{S(3\phi)} = P_{S(3\phi)} + j\,Q_{S(3\phi)} = 3\,V_S\,I_S^*$$

$V_S = A V_R + B I_R$; $I_S = C V_R + D I_R$

$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

$$\begin{bmatrix} V_R \\ I_R \end{bmatrix} = \begin{bmatrix} D & -B \\ -C & A \end{bmatrix} * \frac{1}{|\Delta|} \begin{bmatrix} V_S \\ I_S \end{bmatrix}$$

* $|\Delta| = 1$ $\quad (AD) - (BC) = 1$

$(A = D)$

$V_R = A V_S - B I_S$

$I_S = \frac{A V_S}{B} - \frac{V_R}{B}$

$$I_S = \left|\frac{A\,V_S}{B}\right| \angle \theta_A^\circ + \delta^\circ - \theta_B^\circ - \left|\frac{V_R}{B}\right| \angle -\theta_B^\circ$$

* Finally :-

$$P_{S(3\phi)} = \left|\frac{A\,V_{S(L)}^2}{B}\right| \cos(\theta_B^\circ - \theta_A^\circ) - \left|\frac{V_{S(L)}\,V_{R(L)}}{B}\right| \cos(\theta_B^\circ + \delta)$$

$$Q_{S(3\phi)} = \left|\frac{A\,V_{S(L)}^2}{B}\right| \sin(\theta_B^\circ - \theta_A^\circ) - \left|\frac{V_{S(L)}\,V_{R(L)}}{B}\right| \sin(\theta_B + \delta)$$

※ Losses :-

Real and Reactive transmission Line Losses :-

$$P_{Loss(3\phi)} = P_{S(3\phi)} - P_{R(3\phi)}$$

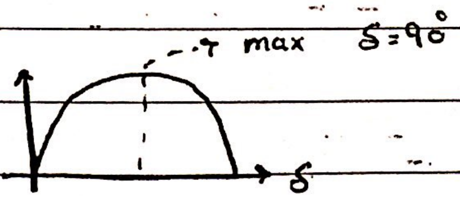
$$Q_{Loss(3\phi)} = Q_{S(3\phi)} - Q_{R(3\phi)}$$

Capacitor
نسمو فيه
VAR Generator
Q

※ Losseless Line :-

$B = Z = \cancel{r} + jx'$ $\quad B = jx'$

$\theta_A = 0^\circ$ $\quad \theta_B = 90^\circ$



* $P_{R\,3\phi} = \left|\frac{V_S V_R}{x'}\right| \sin\delta$

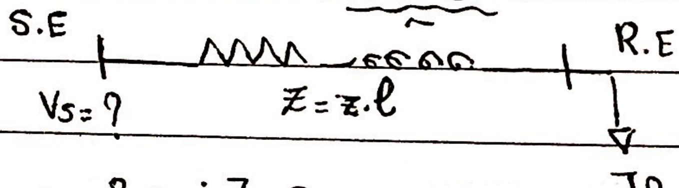
* $Q_{R\,3\phi} = \left|\frac{V_S V_R}{x'}\right| \cos\delta - \left|\frac{V_R^2}{x'}\right| \cos\beta l$ $\quad$ * Voltage → (Line - Line)

2015/5/4

tetorial #

1) A 69-kv, 3-Ph short transmmision Line is (16km) Long. given:-
serias impedance $z = 0.125 + j0.4375\ \Omega/km/ph$
The load at the (R.E) is:-
1) 70 MVA, (0.8 P.f) Lag at (64 kv).
2) 120 MW, (1 P.f) lag at (64 kv).
Coulcalate the Voltage at (S.E), Power at (S.E) and (Voltage Regulation), (Efficiency).

solution



Current Always Per phase

※ $Z = z.l = 2 + j7\ \Omega$

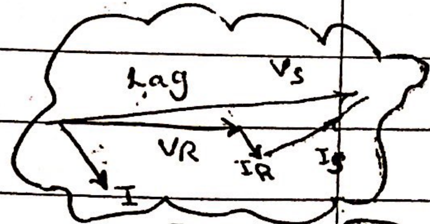
※ $I_R = \frac{70 \times 10^3\ KVA}{\sqrt{3} \times 64\ kV} = \boxed{\ }\ \angle -\cos^{-1} 0.8 = 631.48 \angle -36.87^\circ\ A$

$V_s = A\,V_R + B\,I_R = (1)\,V_R + Z\,I_R = \frac{64 \times 10^3 \angle 0^\circ}{\sqrt{3}} + Z\,(631.48 \angle -36.87^\circ)$

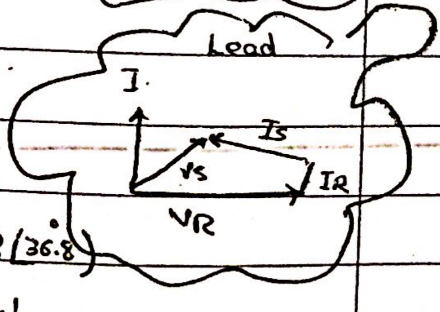
$V_s = 40.7 \angle 3.9^\circ\ kV/ph$

※ $\therefore V_s\,(Line) = \sqrt{3} \times 40.7 = 70.5\ kV$

※ $P_s(3\phi) = 3 \cdot V_{sph}\, I_s \cos\theta_s$
$= 3\,(40.7)(631.48)\cos(40.77)$
$= 58\ MW$



※ $P_{loss} = 3|I|^2 . R = 3\,(631.48)^2 \times 2$
$= 2.3\ MW$

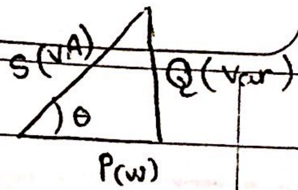


※ $S_s(3\phi) = 3\,\bar{V}_{sph}\, I_s^* = 3\,(40.7 \angle 3.9^\circ)(631.48 \angle 36.8^\circ)$
$= 77.1 \angle 40.77^\circ\ MW$

$V_{Regulation} = \frac{|V_s| - |V_R|}{|V_R|} \times 100 = \frac{70.5 - 64}{64} \times 100 = 10.2\%$

NOTE BOOK

* $\eta = \frac{P_R}{P_S} \times 100 = 96.05\%$

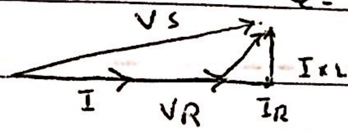


$P = S \cos\theta$

$Q = S \sin\theta$

(B) , $I_R = \frac{120 \times 10^3 \text{ kW}}{1 \times (\sqrt{3}) \times 64 \text{ kV}} \angle 0^\circ$:

الباقي زي نفسه



* Ex :- 2 # A 230-kV, 3Ph line has

$Z = 0.05 + j0.46 \ \Omega/Ph/km$

$y = j3.4 \times 10^{-6} \ S/Ph/km$ $l = 80 km$

using nominal-π model find :-

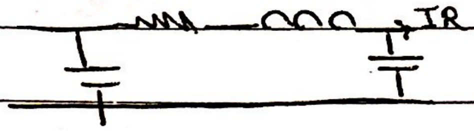
(a) ABCD constant. (B) V_s, I_s, V_R, S_s, η.

The load is 200 MVA at P.f 0.8 , 220 kV

↳ lag

solution

$V_R = 220/\sqrt{3} \angle 0^\circ$ $Z = z\,l = 4 + j36 \ \Omega$



$Y = j\,y\,l$

$= j0.272 \times 10^{-3}$ S

(A)

* $A = 1 + \frac{ZY}{2} = 0.9951 + j0.000544$

$B = Z = 4 + j36 \ \Omega$ $C = Y(1 + \frac{ZY}{4}) = j0.0002713$ S

$D = A$

* (B) * $V_S = A V_R + B I_R = 140.1 \angle 5.7^\circ$ kV

$I_R = \frac{200 \times 10^3 \text{ kVA}}{\sqrt{3} \times 220 \text{ kV}} \angle -\cos^{-1} 0.8$ $V_R = \frac{220}{\sqrt{3}}$ kV

$I_R = 524.86 \angle -36.8^\circ$ A

* $I_S = C V_R + D I_R = 502.4 \angle -33.6^\circ$ A

* $S_{S(3Ph)} = 3 V_S I_S^* = 3(140.1 \angle 5.7^\circ)(502.4 \angle 33.6^\circ)$

$= 211 \angle 39^\circ$ MVA

* $V_{Regulation} = \frac{|\frac{V_S}{A}| - |V_R|}{|V_R|} \times 100 = 10.9\%$

NOTE BOOK

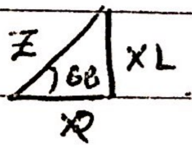
$$\eta = \frac{P_R}{P_S} \times 100 = \frac{200 \times 0.8}{211 \times \cos 39} \times 100 = 98\% .$$

---

* for a lossless line :- (2015/5/4)

$r = 0 \qquad g = 0$

$Z = \underbrace{\cancel{r}}_{zero} + jX_L = jX_L$



$\theta_B = 90^\circ \quad , \quad \theta_A = 0^\circ$

$\gamma = \alpha + j\beta = \sqrt{Zy} = \sqrt{(\cancel{r} + jX_L)(\cancel{g} + j\omega C)}$

$= j\omega\sqrt{LC}$

$\alpha = 0 \qquad \beta = \omega\sqrt{LC}$

$A = \cosh(\gamma l)$

$= \underbrace{\cosh \alpha l}_{1} \cos\beta l + j \overbrace{\sinh \alpha l}^{Zero} \sin\beta l$

* $A = \cos\beta l$

$B = Z_c \sinh \gamma l = Z_c[\overbrace{\sinh \alpha l}^{Zero} \cos\beta l + j \overbrace{\cosh \alpha l}^{1} \sin\beta l]$

* $B = jZ_c \sin\beta l$

$V_S = \cosh\gamma l \; V_R + Z_c \sinh\gamma l \; I_R$ (Lossy Line).

$V_S = \cos\beta l \; V_R + j Z_c \sin\beta l \; I_R$ (LossLess Line).

خالصة 2015/5/7

28/3/2017

AL:daerey...

The distance between the conductors of a single-ph,60-HZ line is 10 ft. Each conductor has 6 stands as shown. The diameter of each strand is 0.1 in. Fine the inductance of the line in mH/mi and the line inductive reactance in ohms/Km.

Quiz #2

2015/4/16

A 3-ph ,60-HZ line is 250 mi long. The parameters of the line are R=0.2 ohm/mi, X=0.8 ohm/mi Y=5.3 *10^(-6) S/mi.

a- The S.E.voltage is 220KV,find the S.E. current when there is no load on the line.

b-If the load at the R.E. is 80 MW at 220 KV with unity P.F., calculate the S.E. voltage

Quiz # 3

A 3-ph 420-KV, 60-HZ transmission line is 460Km long and can be assumed lossless. The line is energized with 420 KV at the S.E.

2015/6/8 Quiz #

When the load at the R.E. is removed, the volage at the R.E. is 702 KV. Ideal reactors are to be installed at the R.E. to keep $|V_S|=|V_R|=420$ KV when the load is removed. Determine the reactance per phase and the required 3-ph reactive power of the reactor.

Scanned by CamScanner

1. Principles of simulation design
2. modeling Methood
3. Performance Evaluation and Result Analysis.
4. Programing in Matlab.
5. Matlab comm sys tools.
6. simulation Applications. (mini project)

$$S = 3\, V_{(PL)}\, I_s^*$$

$$S = 3\,(V_{3\phi})\, I_s$$

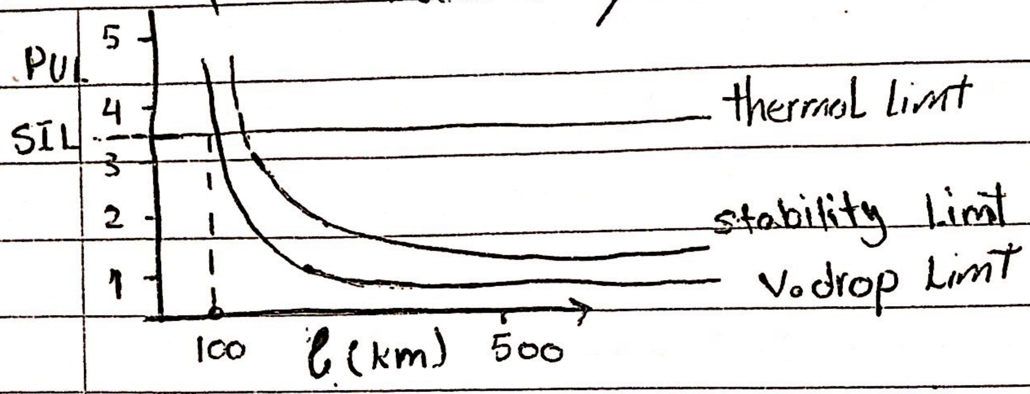
$$S = \cancel{3}\left(\frac{V_L}{\cancel{\sqrt{3}}}\right) I_s$$

$$S = \sqrt{3}\; V_L\; I_s$$

$$I_s = \frac{S}{\sqrt{3}\; V_L}$$

2015/5/11

Loadability Curves



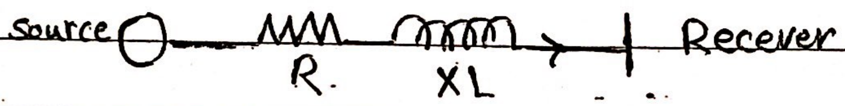
$P = 3.5 * SIL$ $\quad SIL = V^2/Z_C$

$= 1400$ Mwatt

L (400 km)

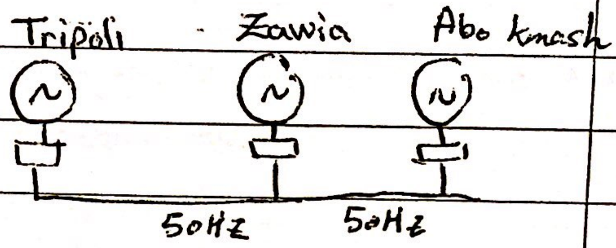
$p = 1.25 * SIL$

$= 1.2 * 400 = 480$ Mwatt

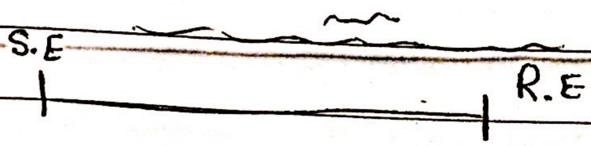


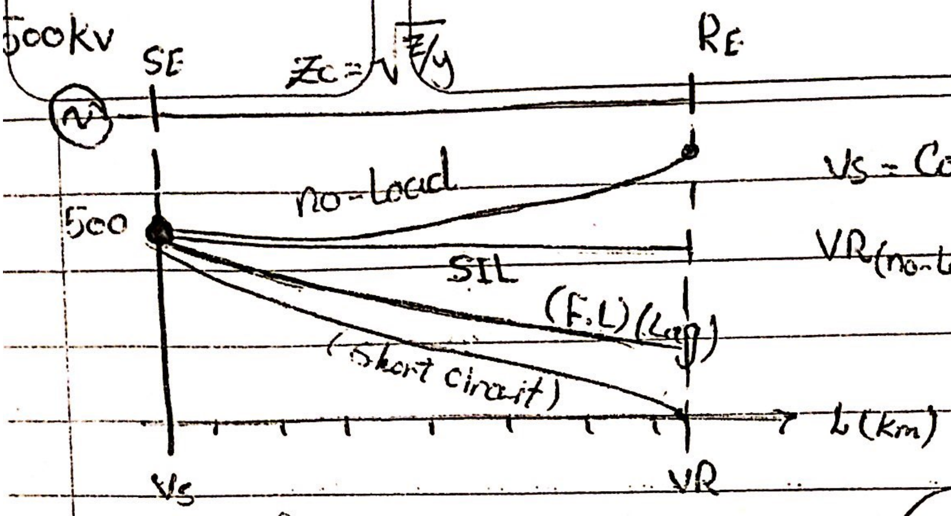
$V.drop = I^* Z$, $\frac{VR}{Vs} \geq 0.95$

$VR = 0.95\ Vs$



(synchronous generators)





$$V_S = \cos\beta l \, V_R + j Z_c \sin\beta l \underbrace{I_R}_{Zero}$$

$$V_{R(\text{no-Load})} = \frac{V_S}{\cos\beta l}$$

※ ferranti - effect :-

الجهد في الخط الطويل لما يكون

بيزيد بسبب (no-Load)

(charging current)

SIL :-

Power = Real Power فقط

$Z_c = R$

$$V_S = V_R(\cos\beta l + j\sin\beta l)$$

$$V_S = |V_R| \angle \theta_R = \beta l$$

※ under (SIL) the voltage magnitude ~~angle~~ along this line is Constant and Equals (VR).

※ Ex :- (1) A 3-ph, 765kv, 60 Hz, 300km transsmision line it has

$Z = 0.0165 + j0.3306 \ \Omega/km/ph$

$y = j\,4.674 \times 10^{-6} \ S/km/ph$

1) find the exact ABCD constants.
2) Compare the exact (B) with that of the nominal (π) Circuit. and (Y/2)
3) Assuming the lossless line find the theoretical steady-state stability limit for the line assuming $\lambda = 5000km$, $V_S = V_R = 765\ kV$
4) calculate the (P_{max}) (Practical) ~~wich can~~ wich can be transmitted given $\delta = 35°$

NOTE BOOK

Solution

$$Z_C = \sqrt{Z/y} = 266.1 \angle -1.43$$

$A = \cosh(\gamma l) = D$ $\qquad \gamma l = \sqrt{Zy}\ .\ l = 0.0931 + j0.37$

$B = Z_C \sinh(\gamma l)$ $\qquad = 0.3731 \angle 88.57^\circ$

$C = 1/Z_C \ \sinh(\gamma l)$

$A = D = \cosh(0.3731 \angle 88.57^\circ) = 0.9313 \angle 0.209^\circ$ per unit

$B = Z_C \sinh(\gamma l) = 97.1 \angle 87.2^\circ \ \Omega \rightarrow$ (exact) #

$C = 1/Z_C \ \sinh(\gamma l) = 1.37 \times 10^{-3} \angle 90.06^\circ \ S$

$B_{(nominal)} = Z = z.l = 99.3 \angle 87.2^\circ \ \Omega \longrightarrow$ (nominal) #

$$\frac{|B_{exact} - B_{nominal}|}{|B_{exact}|} \times 100 = \frac{99.3 - 97.1}{97.1} \times 100 = 2.3\%$$

$(Y/2) = \frac{y}{2} . l = 7.011 \times 10^{-4} \angle 90^\circ S$ (nominal)

$(Y'/2) = \frac{\cosh(\gamma l) - 1}{Z'} = 7.095 \times 10^{-4} \angle 89.97^\circ$ (exact)

$(Y'/2) > (Y/2) \approx 1\%$

for lossless line

$$P = \frac{V_S . V_R}{X'} \sin\delta = \left(V_S(pu) . V_R(pu) . SIL / \sin\left(\frac{2\pi}{\lambda} l\right)\right) \sin\delta$$

$(V_S / V_{S\,rated}) = 1 = (765/765) = 1$ per unit

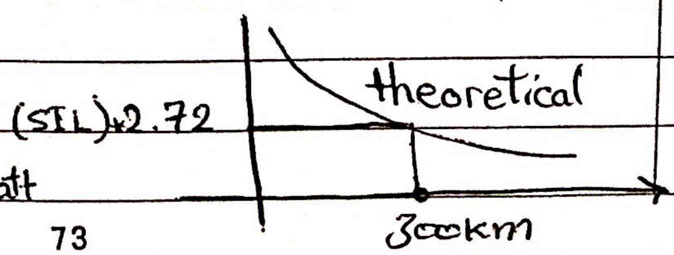
$(V_R / V_{R\,rated}) = 1$ per-unit

$(SIL) = \frac{(V_{S\,rated})^2}{Z_C} = (765)^2 / (266.1) = 2199$ Mwatt

(steady state) $P = \frac{(1)(1)(2199)\ \sin(90^\circ)}{\sin\left(\frac{2\pi(300)}{5000}\right)} = 5974$ Mwatt

$P = SIL * 2.72$

$= (2199)(2.72) = 5974$ Mwatt



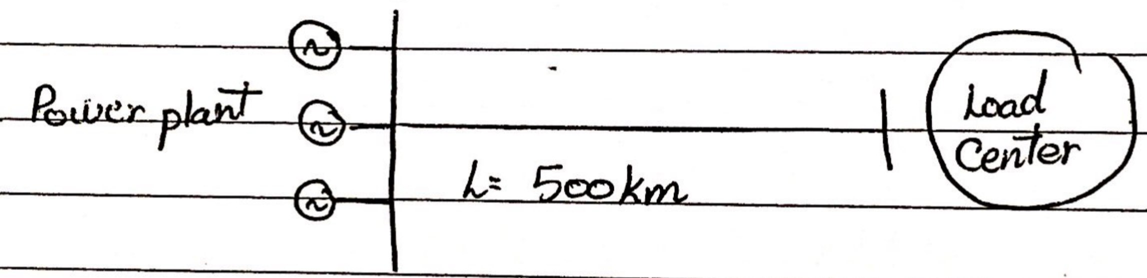
$$P = \frac{|V_S \cdot V_R|}{B} \cos(\theta_B - \delta) - \frac{A V_R^2}{B} \cos(\theta_B - \theta_A)$$

$$P = \frac{(765)(765)}{97.1} \cos(87.2-35) - \frac{0.9313\,(765)^2}{97.1} \cos(87.2-0.209)$$

$P \simeq 3300$ Mwatt $\rightarrow$ practical power.

section of transmission line — 2015/5/14

Voltage and number of lines for Power transfer :-



* Ex:- from a power plant, (9000 MW) are to be transmitted to a load Center located (500km) from the power plant, Based on practical line loadability Criterion, determine the number of (3-ph.) (60 Hz) lines required to transmit this power with One line Out of ~~surface~~ service, for the following cases :-

a) 345-kv , $Z_C = 297\ \Omega$

b) 500-kv , $Z_C = 277\ \Omega$

c) 765-kv , $Z_C = 266\ \Omega$

Solution

neglecting line losses :-

$$P = \frac{V_S V_R}{X'} \sin\delta = \frac{V_S(pu) \cdot V_R(pu)\ (SIL)\ \sin\delta}{\sin(2\pi l / \lambda)}$$

Assume $V_S = 1$ pu $\quad V_R = 0.95$ pu

$\delta = 35^\circ \quad \lambda = 5000$ km

a) 345 kv

$$SIL = \frac{(345)^2}{(297)} = 401\ MW$$

$$P/\text{line} = \frac{(1)(0.95)(401\ MW)}{\sin\left(\frac{2\pi\ 500}{5000}\right)} \sin(35^\circ) = 372\ M\text{watt}$$

$$\underset{\uparrow}{\text{no}} \text{ of } 345\text{kv lines} = \frac{9000}{372} + 1 \cong 26$$

b) 500 kv , $SIL = \frac{(500)^2}{277} = 903$ MW

$$P/\text{line} = \frac{(1)(0.95)(903\ MW)}{\sin\left(\frac{2\pi\ 500}{5000}\right)} \sin 35^\circ$$

$$P/\text{Lin} = 837\ MW.$$

$$\therefore \underset{\uparrow}{\text{no}} \text{ of line} = \frac{9000}{837} + 1 \cong 12$$

c) 765 kv , $SIL = (765)^2/266 = 2200$ MW , $P/\text{Lin} = \frac{(1)(0.95)(2200)}{\sin\left(\frac{2\pi \times 500}{5000}\right)} \sin 35^\circ$

$P/\text{Lin} = 2039$ MW $\qquad$ no of line $= \frac{9000}{2039} + 1 \cong 6$

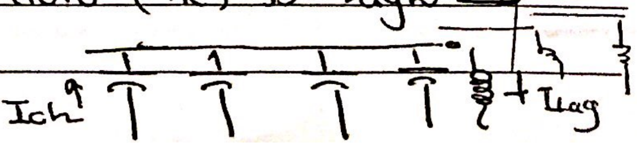
increasing the (V) ~~load~~ level from 345 Kv to 765 Kv has decreased the no of (3ph) Line from (26 $\rightarrow$ 6)

final

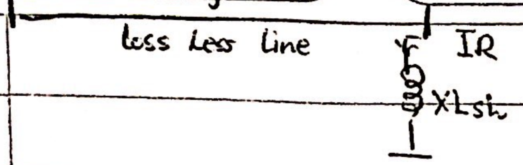
* Transmision line Compensation

هو استخدام معدات للتحكم او تحسين الجهد ؟

* at (SIL) :- the voltage Along the line is Constant &
* at (no-load & Light-load) :- Condition (V_R) is high $\rightarrow$ shunt reactor is needed.



Vs long line VR



$$I_R = \frac{V_R}{XL_{sh}} \quad (1)$$

$$V_s = \cos(\beta l)\, V_R + j Z_c \sin(\beta l)\, I_R \quad (2)$$

(1) into (2) for I_R

- $V_s = \cos(\beta l)\, V_R + j Z_c \sin(\beta l) \cdot V_R / j XL_{sh}$

$$V_s = \left(\cos(\beta l) + Z_c \sin(\beta l)/XL_{sh}\right) V_R$$

$$XL_{sh} = \frac{\sin(\beta l)}{\frac{V_s}{V_R} - \cos(\beta l)} Z_c$$

for $V_s = V_R$, $XL_{sh} = \left(\sin(\beta l) / 1 - \cos(\beta l)\right) Z_c$

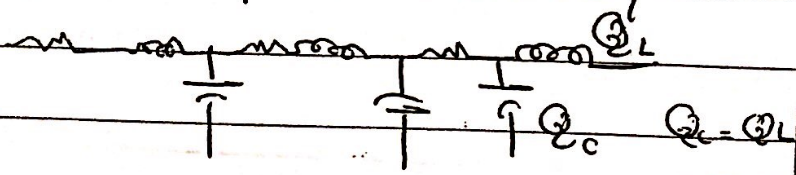
$$Z = \frac{|V|^2_{rated}}{S^*} \qquad S = \frac{|V_{rated}|^2}{Z^*}, \qquad Q = \frac{|V_{rated}|^2}{X_L}$$

Q/phase $\rightarrow$ V_{L-N}

Q/Line $\rightarrow$ V_{L-L}

* note :- At (SIL)

Q generated by shunt cap = Q absorbed by series reactor



$Q_c = Q_L$

2015/5/18

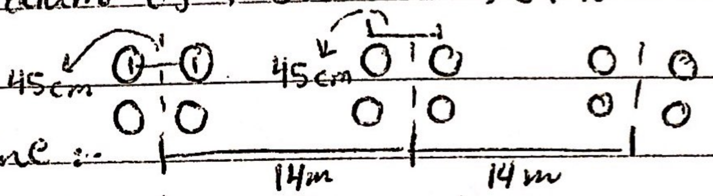
* Problem (5-8) sadat :-

A (3-Ph), 765 kV, 60-HZ line has four ACSR 1431000 cmil 45/7 Bobolink conductor/Ph and flat horizontal spacing of (14 m)

Each Conductor has diam of, 3.625 cm, GMR = 1.439 cm

L = 400 km

Assuming lossless line :-



a) find the (char impedance), phase constant, wave length, SIL, ABCD Constant.

b) find the (R.E) quantities when (1920 MW) and (600 MVAR) are transmitted at (765 kV) at (S.E)

Solution

a) $Z_c = \sqrt{L/C}$

$L = 0.2 \ln \text{GMD}/\text{GMR} \ (\text{mH/km})$, $\text{GMD} = \sqrt[3]{14 \times 14 \times 28} = 17.6\,m$

$\text{GMR}^b = 1.09 \sqrt[4]{1.439 \times (45)^3} = 20.74\,cm$

$L = 0.2 \ln (17.6/0.2074) = 0.89 \ \text{mH/km}$

$C = 0.0556/\ln\left(\frac{\text{GMD}}{r^b}\right)$ $r^b = 1.09 \sqrt[4]{\left(\frac{3.625}{2}\right) 45^3} = 21.97\,cm$

$C = 0.0566/\ln\left(\frac{17.6}{0.2197}\right) = 12.68 \times 10^{-3} \ \mu f/km$

* $Z_c = \sqrt{L/C} = 265\ \Omega$

$B = \omega\sqrt{LC} = 1.26 \times 10^{-3}$ rad/km

$\lambda = 2\pi/\beta = 4986 \approx 5000\,km$

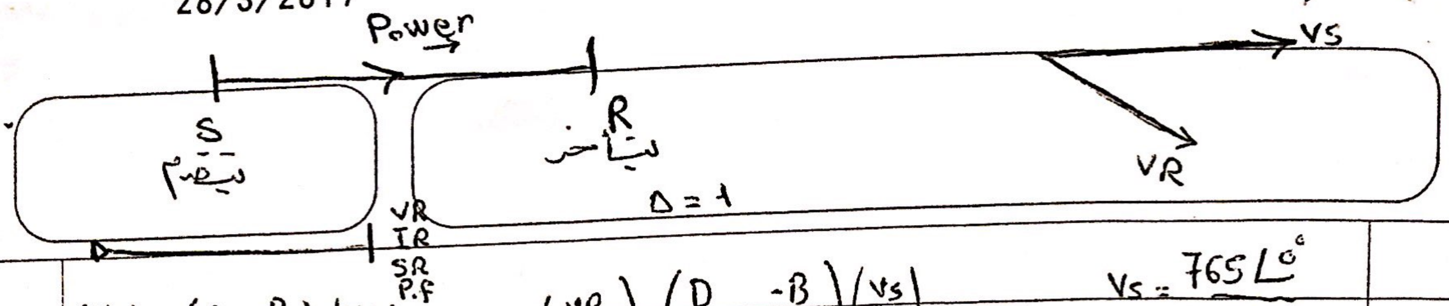
$\text{SIL} = \frac{V_{rated}^2}{Z_c} = \frac{(765)^2}{265} = 2208\ MW$

$A = \cos(\beta L) = 0.876$

$B = j128$ # $C = j1/Z_c \sin\beta L = 1.822 \times 10^{-3}$

$D = A = 0.876$

28/3/2017



$$\begin{pmatrix} V_s \\ I_s \end{pmatrix} = \begin{pmatrix} A & B \\ C & D \end{pmatrix} \begin{pmatrix} V_R \\ I_R \end{pmatrix} \Rightarrow \begin{pmatrix} V_R \\ I_R \end{pmatrix} = \begin{pmatrix} D & -B \\ -C & A \end{pmatrix} \begin{pmatrix} V_s \\ I_s \end{pmatrix}$$

$$V_s = \frac{765 \angle 0^\circ}{\sqrt{3}}$$

$$I_s = \frac{S^*}{\sqrt{3}\, V_s^*} = 1518.14 \angle -17.4^\circ \text{ A}$$

441672.95

$= 3.6 \angle -40.86$

$$V_R = 0.87 \angle 0^\circ \left(\frac{765 \times 10^3 \angle 0^\circ}{\sqrt{3}} \right) - 128 \angle 90^\circ \left(1518.14 \angle -17.4 \right)$$

$V_{R_{Ph}} = 375 \text{ kv} \angle -29.6^\circ$ $\qquad V_R (L\text{-}L) = 649.5 \text{ kv} \angle -29.6^\circ$

$I_R = -C V_s + D I_s$ $\qquad$ (H.w) #3

$I_R = 1325.28 \angle -161.989^\circ$ A

c) if the line is ~~ter~~ terminated in A pure resistive Load, find the (S.E) quantities & Voltage Regulation when the (R.E) load Resist is 264.5 Ω at 735 kv

2015 / 5 / 21

※ Ex :- (2)

A (3-ph) line 300 mil long serves a load of 400 MVA 0.8 Pf lag at 345 kv. The (ABCD) constants of the Line are $(A = D = 0.818 \angle 1.3^\circ)$, $(B = 172.2 \angle 84.2^\circ \ \Omega)$, $(C = 0.001933 \angle 90.45^\circ)$

a) find the no-Load voltage at the (R.E), voltage regulation.

b) A 250-MVAR, 345 kv shunt reactor with $Y = -j\,0.0021$ is Connected at the (R.E) at no-load, (1) find the Equavelent (ABCD) for the line & reactor.

(2) repeat (a) using the equiv (ABCD).

28/3/2017

Solution

$V_S = A V_R + B I_R$

$V_R(\text{no-load}) = \frac{V_S}{A}$

$V_R = \frac{345}{\sqrt{3}} \angle 0°$ KV , $I_R = \frac{400 \times 10^3 \angle -36.87}{\sqrt{3}\ 345} = 669.4 \angle -36.87°$ A

$V_S = A V_R + I_R B = 256. \angle 20°$

$V_{S(L)} = \sqrt{3} \times 256 = 443.75$

$V_R(\text{no-Load}) = \frac{V_S}{A} = 542$

$\therefore$ Regulation $= \frac{542 - 345}{345} \times 100 = 57\ \%$

b) $\begin{pmatrix} A & B \\ C & D \end{pmatrix}_{equv} = \begin{pmatrix} A & B \\ C & D \end{pmatrix}_{line} \times \begin{pmatrix} A & B \\ C & D \end{pmatrix}_{reactor}$

$\begin{pmatrix} A & B \\ C & D \end{pmatrix} = \begin{pmatrix} A & B \\ C & D \end{pmatrix} \begin{pmatrix} 1 & 0 \\ 0.0021j & 1 \end{pmatrix} = \begin{pmatrix} 1.177 \angle -0.8 & 172.2 \angle 84.2° \\ 2.17 \times 10^{-4} \angle 83.2 & 0.818 \angle 1.3° \end{pmatrix}$

$V_R(\text{no-Load}) = \frac{256}{1.17} = 217.31$ (phas)

$= 376.4$ (line)

$\therefore$ Regulation $= \frac{376.4 - 345}{345} \times 100 = 9.1\ \%$

2013/ 5/ 23

ع

* Series Capacitor Compensation :-

$$\uparrow P = \frac{V_S \, V_R}{X - jX_{C\,series}} \sin\delta$$

$Q_L = |I^2| \, X_L$

$-jX_{C\,series}$

jX_L —||— jX_L

* The siries Cap is used to raise the line power Capacity.
* (V) drop is decreased → (V) regulation
* line stability is improved

$Q_C = |I^2| \, X_C$

reactive power is varied Can Currently.

$$\frac{X_{C\,series}}{X} = \text{percent Compisation } (25 \rightarrow 75\%)$$

* Capaciter : VAR Generator

* Ex :- (1) :-

A (3-ph) line, 60 Hz, 500kv, 300 km, has

$L = 0.97$ mH/Ph/km , $C = 0.0115$ μf/Ph/Km

Assume a lossless line :-

* The Load at the (R.E) is (1000MVA), 0.8 P.f lag at 500kv.

a) find (Vs) & V(regulation)

b) series Cap are installed at the (mid-point) of the line providing (40%) comp & find (Vs) & V(regulation).

solution

a) $V_R = \frac{500 \angle 0^\circ}{\sqrt{3}} = 288$ kv $\quad I_R = \frac{1000 \times 10^3}{\sqrt{3} \times 500} \angle -36.87^\circ = 1154 \angle -36.87^\circ$ A

$L = 0.97$ mH/Ph/km $\quad C = 0.0115$ μf/Ph/km

$$\ell\beta = \omega\sqrt{LC}\,\ell = 2\pi(60)\sqrt{(0.97\times10^{-3})(0.0115\times10\times10^{-6})} \times 300 \times \frac{180}{\pi} = 21.64^\circ$$

$$Z_C = \sqrt{L/C} = 290.48$$

$$V_S = (\cos 21.64)(288) + j\,290 = 356.5 \angle 16.11 \text{ kv}$$

$$\text{Voltage Regulation} = \frac{|V_S/A| - V_R}{V_R} \times 100 \simeq 23\%$$

NOTE BOOK

$X_{c\,series} = 0.4 \times 107.11 = 42.8$

$X = X' - X_{c\,series} = 107.11 - 42.8$

$Z' = 64.62 = B_{new}$

$A = 1 + \frac{Z'Y'}{2}$

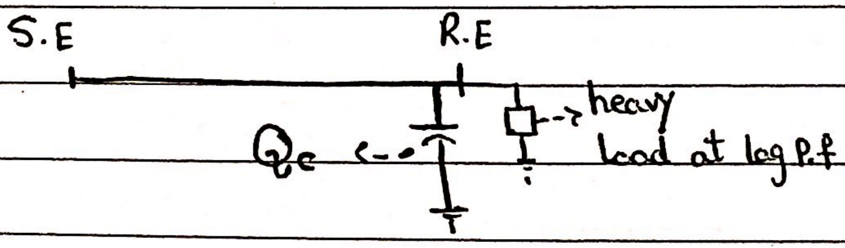
$Y' = j0.0013165$

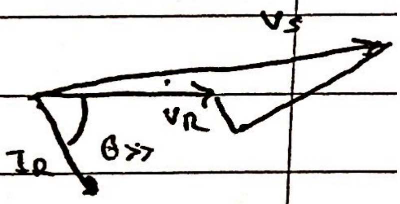
$A_{new} = 1 + \frac{Z'Y'}{2}$

$V_S = A_{new} V_R + B_{new} I_R = 326.4$

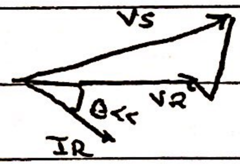
$\text{Regulation}\% = \frac{|V_S/A| - V_R}{V_R} \times 100 = 9.5\%$

※ Shunt - Capacitor Compensation   في 2015/5/28





※ loss less line



$$Q_{R\,3\phi} = \left|\frac{V_S V_R}{X'}\right| \cos\delta - \frac{V_R^2}{X'} \cos\beta l$$

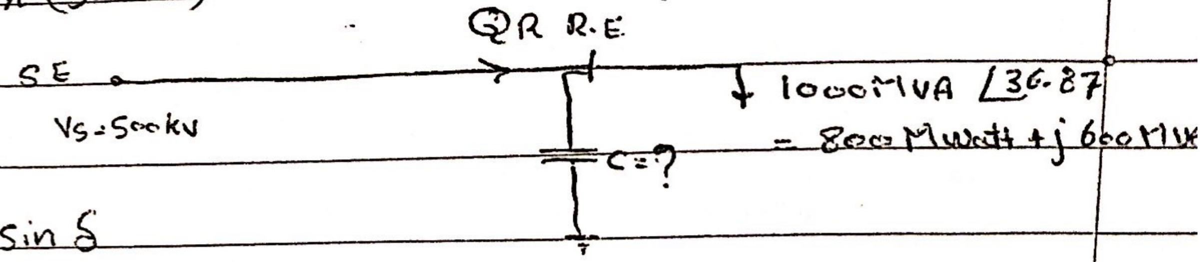
※ ~~Example~~

shunt (cap) are used for lagging P.f circuits created by heavy loads These (cap) supply the Required reactive power to maintain the (R.E) voltage at a Certain level. تثبيت

※ Ex :- (1)

A 3Ø line 60 HZ, 500 kv, 300 km has $L = 0.97$ mH/Ph/km, $C = 0.0115$ μf/Ph/km line is lossless, the load at R.E is (1000 MVA)(0.8 lag).

& 500kv . Determine the (MVAR) & (Cap) of the shunt (caps) to be installed at the (R.E) to keep (V_R) at 500kv when the line is energized with (500kv).



$P_{3\phi} = \left(V_S V_R / x'\right) \sin \delta$

$x' = Z_c \sin \beta l = 107.11 \ \Omega$

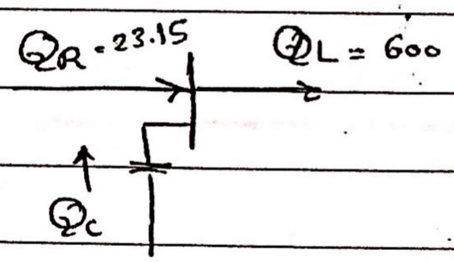
$Z_c = \sqrt{\frac{L}{C}} = 290.43 \ \Omega$

$\beta l = \omega \sqrt{LC} \ l = 21.64°$

$800 = \frac{500 \times 500}{107.11} \sin \delta \implies \delta = 20.044°$

$Q_{R3\phi} = \frac{V_S V_R}{x'} \cos \delta - \frac{V_R^2}{x'} \cos \beta l = \left(\frac{500^2}{107.1}\right) \cos(20.044) - \left(\frac{500^2}{107.1}\right) \cos 21.64°$

$Q_{R3\phi} = 23.15$ MVAR



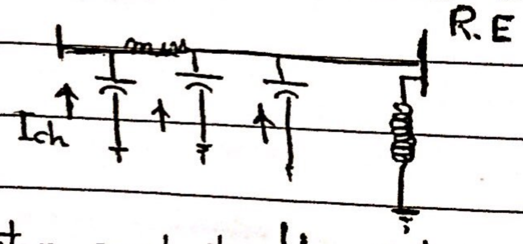
$Q_R + Q_C = Q_L$ <----

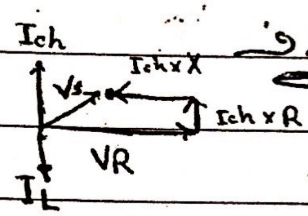
$Q_c = 600 - 23.15 = j576.85$ MVAR

$X_c = \frac{|V^2|}{S_c^*} = \frac{500^2}{j\,576.85} = -j\,433.38 \ \Omega$ $\qquad X_c = \frac{1}{\omega C}$

$C = \frac{1}{2\pi \times 60 \times 433.38} = 6.1 \mu f$

2015 / 6 / 1





$I_1 \xrightarrow{\text{يلغى}} I_c$

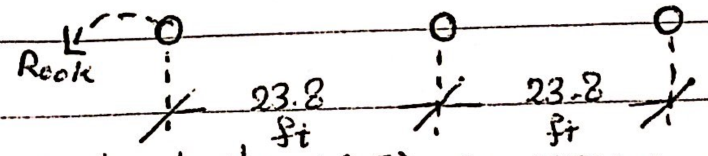
باش الحمل يكون ثابت

Reactor constant = $\begin{vmatrix} 1 & 0 \\ Y & 0 \end{vmatrix}$

$\begin{pmatrix} A & B \\ C & D \end{pmatrix}_{equivalent} = \begin{pmatrix} A & B \\ C & D \end{pmatrix}_{line} \begin{pmatrix} A & B \\ C & D \end{pmatrix}_{shunt-Reactor}$

(H.W #4)

※ Ex:- ① A-(3ϕ), 60 Hz, 230mi Transmision line has Rook conductors, flat horizontal, spacing is 23.8 ft



the load at the (R.E) is 125 MW at (1 p.f) ~~conductors~~ and ~~[illegible]~~ . 215 kv

a) find the Voltage Regulation for un-Compensated line.

b) A shunt Reactor is Connected at the (R-E) during no-Load Condition if the reactor Compensates 70% of the total line admitnse, Calculate the Voltag Regulation of the Componsated line?

Solution

A) $\gamma L = (\sqrt{Zy})\,\ell$

$Z = r + jX_L = r + j(X_a + X_d)$

$GMD = \sqrt[3]{(23.8)(23.8)(47.6)} = 30.15\ ft$

$A = \cosh(\gamma l) = D$

$B = Z_c \sinh(\gamma L)$ $\qquad V_S = A\,V_R + B\,I_R$

$C = 1/Z_c\ \sinh(\gamma L)$

$$\text{Regulation \%} = \frac{\left|\frac{V_S}{A}\right| - V_R}{V_R} \times 100\% = 24.7\%$$

B) $Y_{reactor} = 0.7\ Y_{line}$

$Y_{line} = y.\ell = 0.001174\ S$

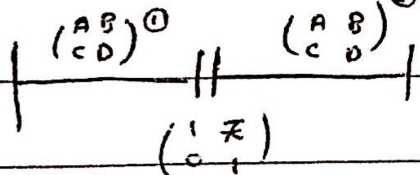
$Y_{reactor} = \left(\frac{70}{100}\right)(0.001174) = -0.000822\ S\ j$

$$\begin{pmatrix} A & B \\ C & D \end{pmatrix}_{eq} = \begin{pmatrix} A & B \\ C & D \end{pmatrix}_{lin} \begin{pmatrix} 1 & 0 \\ -j0.000822 & 0 \end{pmatrix}_{\substack{reactor \\ shunt}}$$

$V_S = \boxed{\quad}$

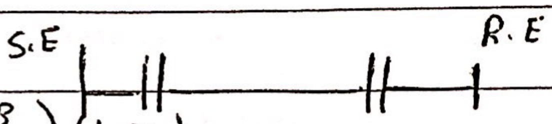
$$VR\% = \frac{\left|\frac{V_S}{A}\right| - V_R}{V_R} \times 100\% = 6.67\%$$

$$\text{Capacitor}_{\text{Reactance}} = \begin{pmatrix} 1 & Z \\ 0 & 1 \end{pmatrix}$$



1

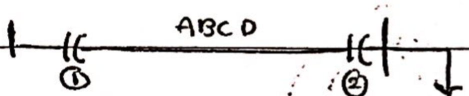
$$* \begin{pmatrix} A & B \\ C & D \end{pmatrix}_{eq.} = \begin{pmatrix} A & B \\ C & D \end{pmatrix} \begin{pmatrix} 1 & Z \\ 0 & 1 \end{pmatrix} \begin{pmatrix} A & B \\ C & D \end{pmatrix}$$



2

$$* \begin{pmatrix} A & B \\ C & D \end{pmatrix}_{eq.} = \begin{pmatrix} 1 & Z \\ 0 & 1 \end{pmatrix} \begin{pmatrix} A & B \\ C & D \end{pmatrix} \begin{pmatrix} 1 & Z \\ 0 & 1 \end{pmatrix}$$

* Ex :.. Problem (5-15) sadat H.w (4) *



$X_{Ct} = 100\ \Omega \rightarrow X_{C_1} = -j\,50\ \Omega,\ X_{C_2} = -j\,50\ \Omega$

$$\begin{pmatrix} A & B \\ C & D \end{pmatrix}_{eq.} = \begin{pmatrix} 1 & -j50 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} A & B \\ C & D \end{pmatrix} \begin{pmatrix} 1 & -j50 \\ 0 & 1 \end{pmatrix}$$

2015 /6/4

* underground Cables :-

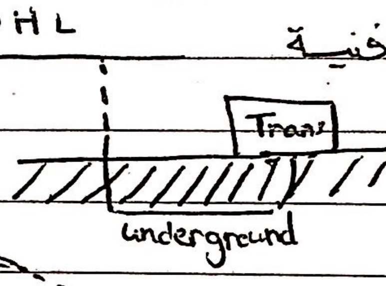
$$C_{(\text{overhead Line})} << C_{(\text{cable})}$$

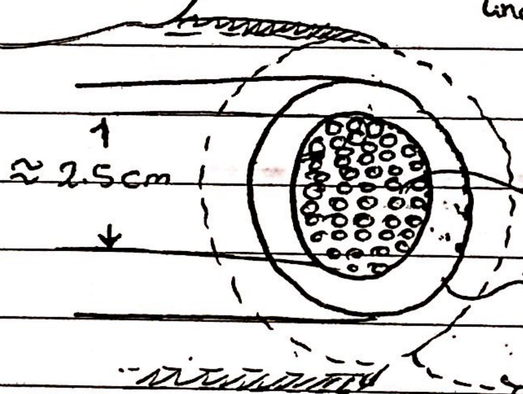
لأن GMD في (OHL) كبيرة هلبا، بينما في GMD (Cable) صغيرة .

$$Z_c(\text{cable}) \approx \frac{1}{10} Z_c(\text{OHL})$$

وكذلك نستخدموها في الأماكن إلي منقدروش نركبو فيها OHL

الإستخدام :-
هنا ناحية فنية نوصل كما في الشكل باش نقص مساحة الحجم





strand conductor
insulation (Pvc rubber)
external Protection
Pvc Anti chemical

All Cable have :-

1. Conductor :- Coppor or Aluminum.
2. insolation :-
3. external Protection (Anti mechanical Dameg)
4. Pvc (Anti Chemical) :

* Ex:- 19/0.1

* strand — diam of each strand

(3/20) AWG American wire Guth.

NOTE BOOK

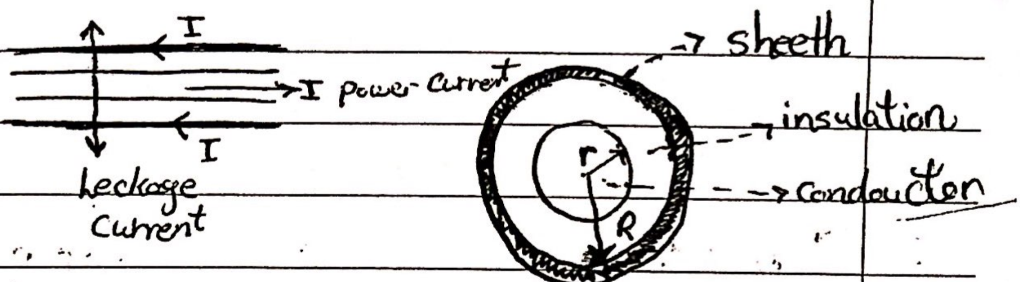
insulation material :-

requirments of insulation materials.

1) very high insulating Resistance ($M\Omega$).
2) high dilectric strength. ← متانة عزل لعزل cond على الأرض وعن cond بعض
3) good mechanical properties.
4) immunity to Chemical attake.
5) non-hygroscopic.
6) not too cost.

* insulation material type :-
- impregnated paper
- rubber - PVC - XLPE ← مستخدم بكثرة في الشبكة الليبية
* (rubber + sulpher) :- vulcanized rubber خواصه ممتازة
* (XLPE) :- Cross - Linked polythene → (250c° - 300c°)

* insulation Resistance of a Cable :-



$dR_{(insulation)} = \rho \frac{l}{A}$, ρ = specific resistance of dilectric

$A = 2\pi(x)\ 1m$: l = length of current path

$l = \Delta x = dx$. A = Cross section Area normal to flow of Leakge Current

$$dR = \rho \frac{dx}{2\pi(x) \cdot 1}$$

$$R_{(insulation)} = \frac{\rho}{2\pi}\int_r^R \frac{dx}{x} = \frac{\rho}{2\pi} \ln\frac{R}{r}$$

for l (m)

$$R_{ins} = \frac{\rho}{2\pi l} \ln\frac{R}{r} \rightarrow * \; (\Omega)$$

* Ex:- A single core cable (1 core cable). has core diam of 2.5 cm insulation thickness of 1.25 cm.
$\rho = 4.5 \times 10^{14}\ \Omega\text{-cm}$
Calculate R_{ins}/Km?

Solution

$$R = \frac{\rho}{2\pi l} \ln\frac{R}{r} = \frac{4.5\times10^{14}\ \Omega\text{-cm}}{2\pi\ (\underbrace{10^5\ \text{cm}}_{1\ \text{km}})} \ln\left(\frac{\left(\frac{2.5}{2}\right)+1.25}{1.25}\right)$$

$R_{ins} = 496\ M\Omega$

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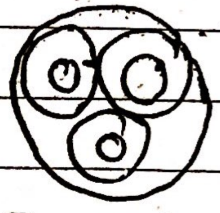
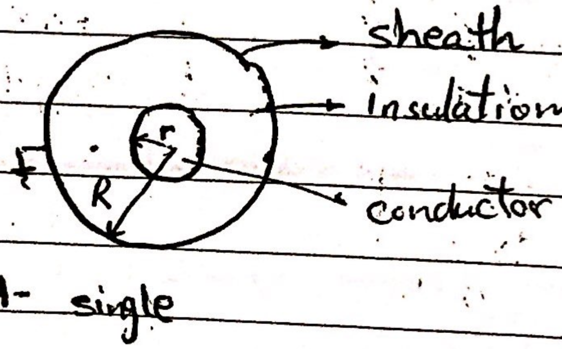
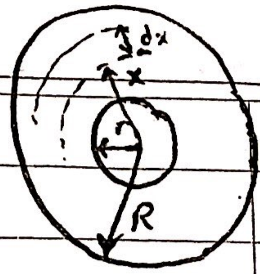
※ Capacitance of single Core Cable:-





$$E_x = \frac{Q}{2\pi \epsilon x} \; V/m \quad , \quad \epsilon = \epsilon_o \epsilon_r \longrightarrow (1)$$



ϵ = permativity of insulation material

E_x = Electric field intensity

$V = \int_r^R E_x \, dx$ = Voltage Conductor (w.r.t) sheath.

$$V = \int_r^R \frac{Q}{2\pi \epsilon x} = \frac{Q}{2\pi \epsilon_o \epsilon_r} \ln \frac{R}{r} \longrightarrow (2)$$

$$C = \frac{Q}{V} = \frac{2\pi \epsilon_o \epsilon_r}{\ln(\frac{R}{r})} \; f/m = \frac{0.0556 \, \epsilon_r}{\ln(\frac{R}{r})} \; \mu f/Km$$

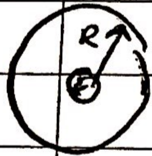
Capacitanc (cable) >>> Capacitane (over head line)

Ich (cable) >> Ich (over head line).

(2) for (1) : $\longrightarrow$ Q :-

$$E_x = \frac{V \cdot 2\pi \epsilon_o \epsilon_r}{\ln(\frac{R}{r})} \cdot \frac{1}{2\pi \epsilon_o \epsilon_r x}$$

$$E_x = \frac{V}{x \ln(\frac{R}{r})}$$



* $E_{max} = \dfrac{V}{r \ln(\frac{R}{r})}$ (1)

* $E_{min} = \dfrac{V}{R \ln(\frac{R}{r})}$ (2)

The min value of (E_{max}) at the surface of the Conductor is when

$$\frac{\partial E_{max}}{\partial r} = 0 = \frac{0 - V\left[\ln(\frac{R}{r}) - 1\right]}{\left(r \ln(\frac{R}{r})\right)^2} = 0$$

$$= -\frac{V}{(r \ln(\frac{R}{r}))^2} \left(\ln(\frac{R}{r}) - 1\right) = 0$$

$$\ln(\frac{R}{r}) = 1 \qquad \frac{R}{r} = e^1 = 2.718$$

$$R = r\,(2.718)$$

NOTE BOOK

* Ex :- ①

Determine the most economic diameter of a (1-core) cable, metal sheathed the working Voltage is (85kv), And the ~~elect~~ delectric strength of the insulating material is (65 kv/cm)

for economic size, $\frac{R}{r} = 2.718$

$V = E_{max}\, r \ln\left(\frac{R}{r}\right)$

$E_{max} \leq$ dielectric strength

$85 = 65\,(r)\,(1)$

$r = \frac{85}{65} = 1.3$ cm

cond. diameter $= 2(r) = 2(1.3) = 2.6$ cm

sheath. diameter $= 2.718 \times 2 \times 1.3 = 7.07$ cm

* Ex :- ②

Calculate the Capacitance And charge current of a single Core Cable used on 66kv supplay, 3-ph 50-Hz system.

3 single Core

the Cable is (1 km) long

3-Ph

Core diameter (15cm) sheath diameter (60cm), $\epsilon_r = (3.6)$

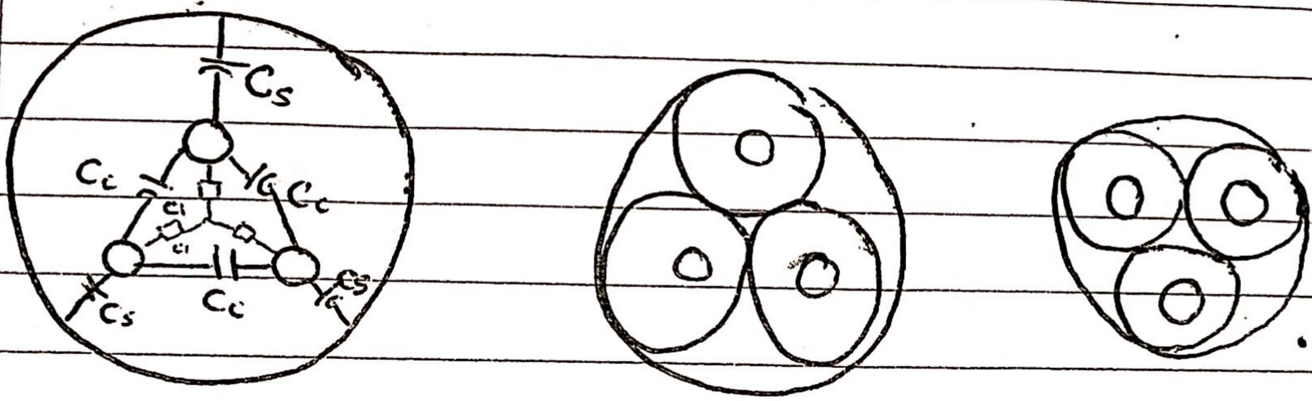
nutral

$C_n = \frac{0.0556\, \epsilon_r}{\ln \frac{R}{r}} = \frac{0.0556 \times 3.6}{\ln\left(\frac{60/2}{15/2}\right)} = 0.145\ \mu f/km$

$I_{ch} = w\, C_n\, V_{ph}$

$= 2\pi \times 50 \times 0.145 \times 10^{-6} \times \left(66 \times 10^{3} / \sqrt{3}\right) = 1.74\ A/km$

※ Capacitance of 3-core belted Cables :-



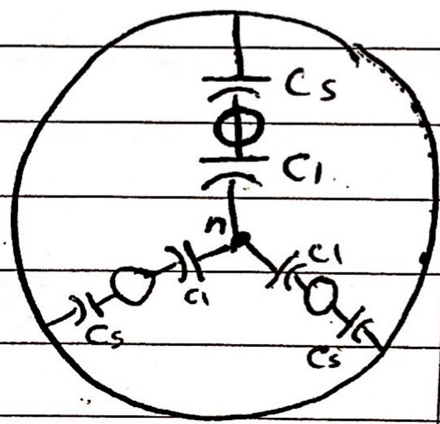
using (Δ-Y) transfer :-

$$Z_Y = \frac{1}{3} Z_\Delta$$

$$\frac{1}{\cancel{\omega} C_1} = \frac{1}{3} \cdot \frac{1}{\cancel{\omega} C_c}$$

$C_1 = 3C_c$

if the neutral point is at zero potential, And sheathe is also at zero poten



$C_1 // C_s$

$C_0 = C_1 + C_s$

$C_0 = 3C_c + C_s$

$C_0 = 3/2 \ C_a - \frac{C_b}{6}$

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NOTE BOOK

※ Ex:-

3-Ph, 3-core, metal sheathed cable gave following Results on test:

i) Cap between bunched conductors & sheath is 0.625 μf/km.

ii) Cap between two Conductors bunched with sheath & third Conductor is 0.4 μf/km.

Determine

a) the cap between any two conductors.

b) the cap between any two bunched conductors.

c) the changing current /Ph/Km when the cable is Connected to 10 kv, 50Hz supply.

solution

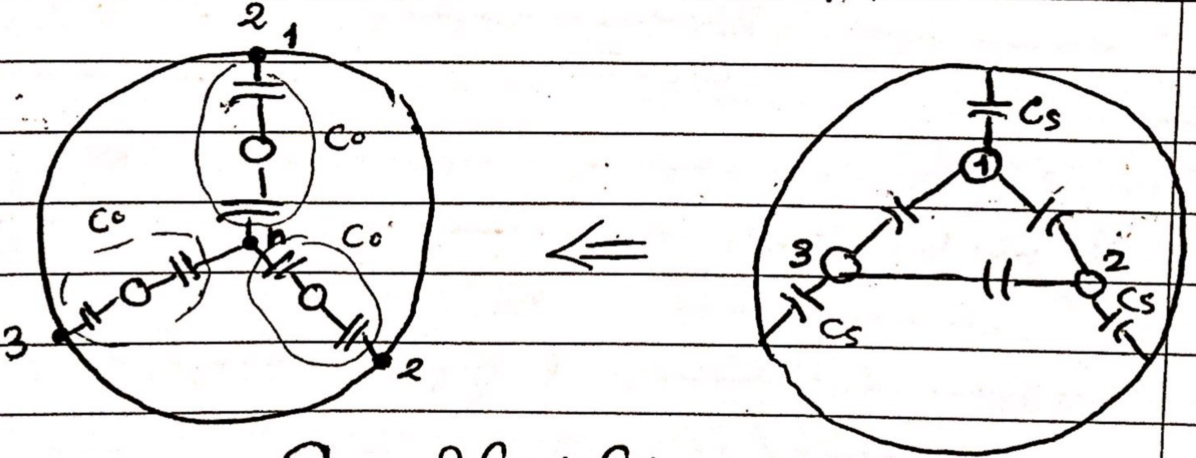
a)

$C_b = 0.625\ \mu f/Km = 3C_s \qquad C_s = \frac{0.625\ \mu f/km}{3}$

$C_s = 0.20833\ \mu f/Km$

$C_a = 0.4 = 2C_c + C_s$

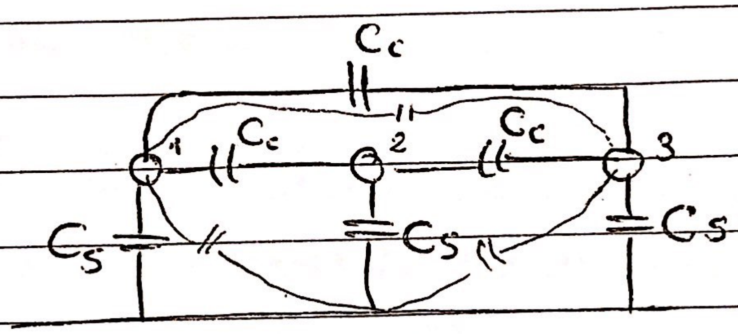
$C_c = \frac{0.4 - 0.20833}{} = 0.0958\ \mu f/km$

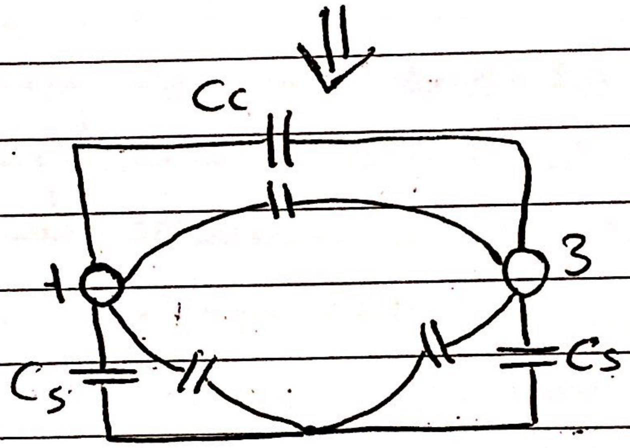


$\underset{(\text{nutral})}{C_o} = 2C_c + C_s$

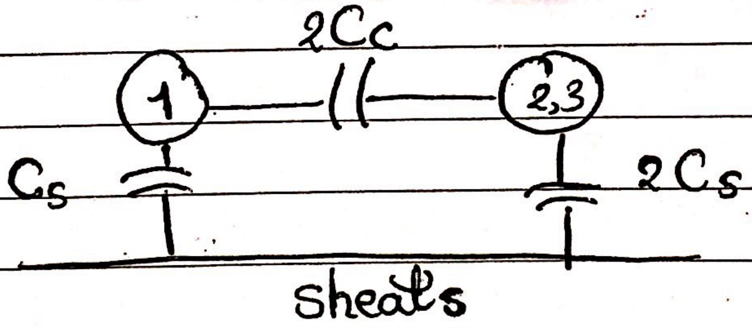
$= 2(0.0958) + (0.20833) = 0.496\ \mu f/km$

$$C_{12} = \frac{C_o * C_o}{(C_o + C_o)} = \frac{C_o^2}{2C_o} = \frac{C_o}{2} = \frac{0.496}{2} = 0.248\ \mu f/km$$





b)



$$C_{23,1} = 2C_c + \frac{C_s \cdot 2C_s}{(C_s + 2C_s)} = 2C_c + \frac{2C_s}{3}$$

$$C_{23,1} = 2(0.0958) + \frac{2}{3}(0.20833)$$
$$= 0.33\ \mu f/km.$$

c) $I_{ch} = \omega C_o V_p$

$$= 2\pi(50)(0.496 \times 10^{-6}) \times \frac{10000}{\sqrt{3}} = 0.899\ A/km$$

* Ex:- #2

A single core (1-core), cable of (5km) long has a conductor diam of (2cm), inside diam of sheath of (5cm). The cable is used at ~~49.9kv~~ (24.9 kV) & 60 HZ Calculate :-

a) (max) & (min) electric stress.

b) optimum value of conductor radius that gives min value of max. stress.

solution

$$E_{max} = \frac{V}{r \ln \frac{R}{r}} = \frac{\cancel{49.9}\ 24.9}{1 \ln\left(\frac{2.5}{1}\right)} = 27.17\ kv/cm$$

$$E_{min} = \frac{24.9}{2.5 \ln \frac{2.5}{1}} = 10.87\ kv/cm$$

$$r = \frac{R}{2.718} = \frac{2.5}{2.718} = 0.92\ cm$$

min value of max stress $= \dfrac{24.9}{0.92 \ln \frac{2.5}{0.92}} = 27.07\ kv/cm$

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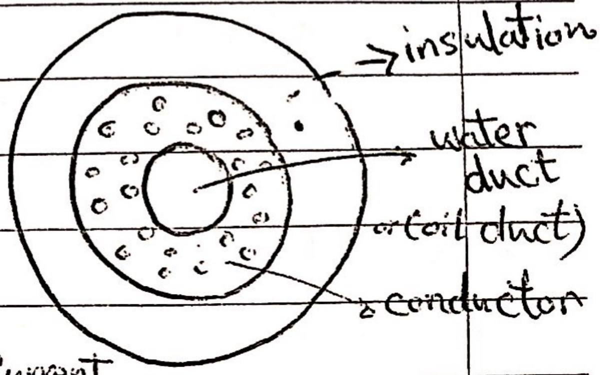
heating of Cables :-

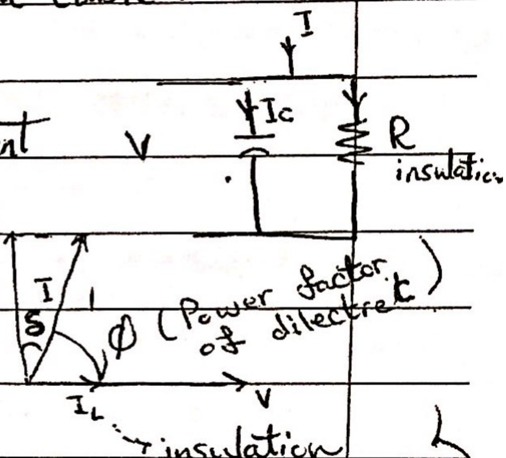
rate of heat of heat Generation → body → rate of heat dissipation



sources of heat generation is underground Cables :-

1) Core loss : $|I^2| * R$, I = load Current carried by the Cable.

2) dielectric loss : ⓐ Power loss due to the flow of Leakage current throgh ($R_{insulation}$).



ⓑ Hysteresis losses

$\cos \phi$ = Power factor of dile

$\sin \delta$ = " " "

dielec Power loss = $V I \cos \phi$

" " $= V I (\sin \delta)$ δ

" " $= V(wcV)\delta$

" " $= wcV^2 \delta$

3) sheath loss

Total loss dielec = hysteresis loss + Ploss du to the flow leakage current throgh (R_{insul})

hyster >> Ploss due to flow

Ex :- # 1

A single-Core Cable has a Counductor diam of (0.814 in) , inside diam of sheath of (2.442 in) and a length of (3.5 mi) The cable is Operated at (60 HZ) , (7.2 kv) The dielectriec Constant is (3.5) And the (P.f) of the dielectric on Open Circuit at Rated (f) & (V) is (0.03) the insulation resistivity is ($1.3 * 10^7$ M Ω/cm).

Calculate :-

) (Max) stress in the dielec

b) cap of the cable.

c) charging Current

d) insulation resister.

e) Power Loss due to Lakege current troght (Rinsulation)

f) total dielec loss.

g) hyst. loss.

Solution

$$r = \frac{0.814}{2} * 2.54 = 1.03 \text{ cm}$$

$$R = \frac{2.442}{2} * 2.54 = 3.1 \text{ cm}$$

a) $$E_{max} = \frac{V}{r \ln \frac{R}{r}} = \frac{7200}{1.03 \ln\left(\frac{3.1}{1.03}\right)} = 6.34 \text{ KV/cm}$$

b) $$C = \frac{0.0556\, \epsilon_r}{\ln (R/r)} = \frac{0.0556\,(3.5)}{\ln(3.1/1.03)} = 0.18 \ \mu f/km * 3.5 * 1.6$$

$$= 0.996\ \mu f$$

c) $$I_{ch} = W C V$$

$$= (2\pi * 60)(0.996 * 10^{-6})(7200) = 2.7 \text{ A}$$

d) $R_{insulation} = \frac{\rho}{2\pi l} \ln\left(\frac{R}{r}\right) = \frac{1.3*10^{7}\ M\Omega\text{-}cm}{2\pi\ (3.5mi * 1609 * 100)} \ln\left(\frac{3.1}{1.03}\right)$

$R_{insulation} = 4\ M\Omega$

e) $P_{\text{loss due to Lakege cubrent}} = \frac{V^2}{R_{insulation}} = \frac{(7200)^2}{4*10^6} = 12.85\ \text{Watt}$

f) $P_{total} = WCV^2\,\delta \dashrightarrow \text{rad}$

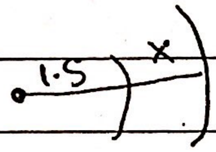
$= (2\pi\, 60)(0.996*10^{-6})(7200)^2(0.03) = 584\,w$

g) $P_{hyst} = P_{total} - P_{R_{insulation}} = 584\,w - 12.85\,w = 571.16\ \text{Watt}$

$R = \frac{\rho}{2\pi L} \ln \frac{R}{r}$

$480 = \frac{\rho}{2\pi l} \ln \frac{2}{1}$

$960 = \frac{\rho}{2\pi L} \ln \left(\frac{x + 1.5}{1.5}\right)$ W



$\frac{1}{2} = \frac{\ln 2}{\ln W}$

$\ln W = 2\ln 2$

$W = e^{2\ln 2} = 4$

$W = 4 = \frac{1.5 + x}{1.5}$

$X = 4.5\ mm$